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Neural responses to social evaluation: The role of fear of positive and negative evaluation

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ABSTRACT

One of the core features of social anxiety disorder (SAD) is the persistent fear of being evaluated. Fear of evaluation includes fear of negative evaluation (FNE) and fear of positive evaluation (FPE). Few studies have examined the relationship between self-reported FNE and FPE and neural responses to simulated negative and positive social evaluation. In the current study, 56 participants, 35 with SAD and 21 healthy controls, completed questionnaires to assess dimensions of social anxiety including FNE and FPE, as well as symptoms of anxiety and depression. Participants also completed a social evaluation task, which involved viewing people delivering criticism and praise, and a control task, which involved counting asterisks, during functional magnetic resonance imaging. Although whole-brain analyses did not reveal significant associations between self-reported constructs and neural responses to social evaluation, region of interest analyses for the sample as a whole revealed that both FNE and social anxiety symptoms were associated with greater neural responses to both criticism and praise in emotion-processing brain regions, including the amygdala and anterior insula. There were no significant associations between FPE or depressive symptoms and neural responses to criticism or praise for the sample as a whole. Future research should examine the relationship between FNE, FPE, and neural responses to self-referent social evaluation in an unselected sample to assess a full range of fear of evaluation.

1. Introduction

Social anxiety disorder (SAD) is defined by persistent fears of one or more social situations (American Psychiatric Association, 2013). Persistent fears in SAD include both fear of negative evaluation (FNE), characterized by distress associated with receiving negative evaluation from others, and fear of positive evaluation (FPE), characterized by distress associated with receiving positive evaluation from others.

Although SAD research has traditionally focused on FNE, which has been identified as a core feature of the disorder (Clark & Wells, 1995; Rapee & Heimberg, 1997), recent research has proposed a two-factor model including FNE and FPE as separate, but correlated factors. Results suggest that this model – the bivalent fear of evaluation (BFOE) model – is a better fit than a single-factor fear of evaluation model, supporting the separate consideration of FNE and FPE (Weeks, Heimberg, & Rodebaugh, 2008), and additional research has supported this separation (Gilbert, 2001; Reichenberger, Wiggert, Wilhelm, Weeks, & Blechert, 2015; Rodebaugh, Weeks, Gordon, Langer, & Heimberg, 2012; Weeks, Heimberg, Rodebaugh, & Norton, 2008; Weeks, Jakatdar, & Heimberg, 2010).

Research inspired by the BFOE model has examined how individuals respond to positive and negative evaluation, and what role FNE, FPE, and associated constructs play in these responses. Wieser, Pauli, Weyers, Alpers, and Mühlberger (2009) found that FNE was associated with initial and more frequent orientation towards emotional, compared to neutral, faces during the first viewing and avoidance of those faces in subsequent viewings. Additional research has found an association between FNE and avoidance of emotional faces (Garner, Mogg, & Bradley, 2006; Mansell, Clark, Ehlers, & Chen, 1999; Weeks, Howell, & Goldin, 2013). Moreover, consistent with the BFOE model, FNE was associated with greater ratings of the unpleasantness of negative films and greater experience of personal pride following positive films, whereas higher FPE related to greater ratings of the unpleasantness of positive films and lesser experience of pride following positive films

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(Reichenberger et al., 2015).

Additional studies have examined the role of FNE and FPE in the interpretation of, and response to, real or prospective evaluation. For instance, Dryman and Heimberg (2015) examined interpretation bias using a word-sentence association paradigm that required individuals to pair sentences (e.g., "People laugh after something you said") with one of two corresponding words, either negative/threatening (e.g., "embarrassing") or positive/benign (e.g., "funny"). Undergraduates with higher levels of FPE were more likely to make negative interpretations of sentences and respond more quickly. This association was not found in the related endorsements and rejections of negative and positive word-sentence pairs. This suggests that FPE may play an important role in negative interpretation bias during more immediate processing rather than reflective processing.

As the BFOE model suggests that FPE relates more strongly to disqualification of positive outcomes related to the self than FNE (Weeks & Howell, 2012), it is possible that individuals with higher levels of FPE make quick and negative interpretations of both negative and positive evaluation at the immediate level of processing. Barber and Moscovitch (2016) examined FNE and FPE in the context of a lab-based task designed to evoke social threat in undergraduates with high and low levels of trait social anxiety. High socially anxious participants experienced higher levels of state anxiety throughout the study and expected a higher likelihood of receiving negative evaluation and lower likelihood of receiving positive evaluation. However, both high and low socially anxious individuals anticipated an equivalent increase in anxiety at the prospect of receiving negative evaluation. Unexpectedly, all participants anticipated that their anxiety would decrease when anticipating positive evaluation. This finding suggests that positive evaluation may be less anxiety-provoking than negative evaluation even for socially anxious individuals. This latter finding may be attributable to disqualification of positive outcomes (i.e., one reasonably does not expect to feel afraid of an outcome they expect *not* to occur), as well as other constructs suggested by the BFOE, including trait negative affect and automatic thoughts. These findings may explain some of the mixed literature surrounding FPE and response to social evaluation.

The impact of FNE and FPE on neurobiological responses to social evaluation, or anticipated evaluation, in non-clinical populations has been examined. Generally, several brain regions have been implicated in emotional and social-processing, including the amygdala (Frewen et al., 2010), anterior insula (Craig, 2009; Gu, Hof, Friston, & Fan, 2013; Lamm & Singer, 2010; Singer, 2004), posterior insula (Singer, 2004), and medial frontal cortex (Menon & Uddin, 2010). Miedl et al. (2016) examined the responses of healthy participants to videos of actors expressing positive, negative, and neutral statements and the role of levels of FNE and FPE specifically and found greater activation in the medial prefrontal cortex (mPFC) and rostral anterior cingulate cortex (ACC) during positive and negative evaluation than during neutral statements. In addition, relative to neutral statements, positive and negative statements were both associated with greater amygdala responses; however, only negative statements were associated with increased anterior and posterior insula activation. Greater FPE was associated with increased posterior insula activity in response to positive, but not negative, statements, suggesting heightened interoception to positive evaluation, whereas no associations were seen between FNE and neural responses.

Neural responses to social evaluation in individuals with SAD have also been examined. In a study that utilized negative, neutral, and positive verbal-statements about self or others, individuals with generalized SAD demonstrated greater blood-oxygen level dependent (BOLD) signal responses in the mPFC and bilateral amygdala to criticism referring to themselves compared to individuals without SAD. However, there were no significant differences in BOLD signal responses to criticism referring to others or neutral or positive comments referring to self or others (Blair et al., 2008). In a follow-up study, individuals with SAD showed increased neural responses to second person viewpoints (e.g., "You're beautiful") relative to first person viewpoints (e.g., "I'm beautiful") in the mPFC. This response to first person viewpoint comments was negatively associated with severity of social anxiety symptoms (Blair et al., 2011). Similarly, Heitmann et al. (2014) found that greater social anxiety was associated with deactivation of medial prefrontal brain regions during anticipation of negative feedback relative to positive feedback and the control (i.e., neutral) condition, and increased activation in the medial prefrontal regions and insula during the presentation of negative and positive feedback compared to the (neutral) control condition.

Another study examined the relationship between neural response to social feedback and social anxiety using videos of actors making negative facial expressions and statements (e.g. "I hate you"), neutral facial expressions and statements (e.g. "I'm late"), and positive facial expressions and statements (e.g. "I'm proud of you"). Results showed that social anxiety was associated with a more unpleasant experience of negative social evaluation and a less positive experience of positive social evaluation (Wiggert, Wilhelm, Reichenberger, & Blechert, 2015). In addition, higher levels of FNE were associated with greater reports of arousal while watching negative videos, whereas high levels of FPE were associated with less pleasant reports while watching positive videos. FNE and FPE are associated with neural responses to social evaluation in non-clinical samples, and FNE appears to be associated with neural response to social evaluation in clinical samples as well. As such, it is imperative to understand how FNE and FPE function in, and contribute to, different mental disorders, including SAD.

The goal of the present study was to investigate whether levels of self-reported FNE and FPE were associated with neural responses to criticism and praise in individuals with and without SAD. Previous research has not examined whether FNE and FPE are associated with specific neural activation patterns including in individuals with SAD to assess a broad dimensional range of FNE and FPE. In research with healthy controls, Miedl et al. (2016) found that although individuals demonstrated greater activation in the amygdala in response to positive and negative statements, relative to neutral statements, and greater anterior and posterior insula activation in response to negative statements, only FPE was associated with greater activation in the posterior insula in response to positive, but not negative statements. No associations were seen between FNE and neural responses. Given the research implicating the amygdala and insula in social and emotional processing in both individuals with SAD (e.g., Blair et al., 2008; Heitmann et al., 2014) and healthy controls (e.g., Craig, 2009; Frewen et al., 2010; Singer, 2004) and the broad dimensional range of FNE and FPE assessed in the current sample, we hypothesized that higher levels of FNE would be associated with increased BOLD responses to criticism relative to the control task in the amygdala and anterior and posterior insula. Similarly, we hypothesized that higher levels of FPE would be associated with increased neural responses to praise relative to the control task in the amygdala and anterior and posterior insula.

A secondary aim was to examine the specificity of the associations between FNE and FPE and neural responses to social evaluation relative to general symptoms of social anxiety and depression. Previous research has suggested that regardless of concurrent depression, individuals with SAD are more likely to demonstrate an interpretation bias for negative social events (Wilson & Rapee, 2005). However, when considering the interpretation of positive social events, the disqualification of positive events and outcomes was not significant after controlling for depression. Additional research has suggested that FPE is associated with depression (Reichenberger, Wiggert, Agroskin, Wilhelm, & Blechert, 2017), whereas other studies suggest that FPE is unique to social anxiety and that FNE relates to both social anxiety and depression (Kocijan & Harris, 2016; Wang, Hsu, Chiu, & Liang, 2012; Weeks, 2015). These mixed results highlight the need to understand the mechanisms underlying FNE and FPE, such as by examining neural response to social evaluation. It is also important to consider social anxiety and depression when examining the relationships of FNE and FPE

to neural response to social evaluation in order to differentiate these effects. We hypothesized that greater symptoms of social anxiety would be associated with increased BOLD responses to both criticism and praise in bilateral amygdala and insular cortex. We also hypothesized that FNE and FPE would predict neural responses to criticism and praise, relative to the control condition, above and beyond that accounted for by depressive symptoms in the amygdala, anterior insula, and posterior insula.

2. Method

2.1. Participants

Fifty-six adults (30 male) participated in the current study. Participants included 35 individuals with SAD who were recruited for a larger randomized control trial (RCT) study examining cognitive behavioral therapy (CBT) outcomes for individuals with SAD and 21 healthy controls who did not meet criteria for any psychiatric disorders (see Goldin et al., 2012, 2014). Participants ranged from 21 to 53 years of age (*Mean (M)* = 32.63, *Standard*

Standard Deviation (SD) = 9.06). Of these participants, 35 met DSM-IV (American Psychiatric Association, 1994) criteria for a principal diagnosis of generalized SAD. All participants were screened for current pharmacotherapy or psychotherapy, past CBT, and history of medical or neurological disorders. In the full sample, 30 (53.6%) participants reported their ethnicity as Caucasian, 15 (26.8%) as Asian, five (8.9%) as Hispanic/Latino, two (3.6%) as Filipino, one as African American (1.8%), one (1.8%) as Pacific Islander, and two (3.6%) as more than one ethnicity. Demographic data for each group are presented in Table 1.

2.2. Procedure

Participants reviewed procedures and provided informed consent. Participants completed a telephone screen and in-person diagnostic interview and met the criteria for a principal diagnosis of generalized SAD based on the Anxiety Disorders Interview Schedule for the DSM-IV: Lifetime Version (ADIS-IV-L; DiNardo, Brow, & Barlow, 1994; participants with SAD) or no psychiatric disorders (healthy controls). Eligible participants also had to pass a magnetic resonance imaging (MRI) safety screen and be right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971). Patients were excluded if they did not meet any of the aforementioned criteria and if they reported current pharmacotherapy or psychotherapy, past CBT, history of medical or neurological disorders, or met diagnostic criteria for any psychiatric condition other than generalized anxiety disorder, agoraphobia without panic attacks, specific phobia, panic disorder, or dysthymia (see Goldin et al., 2012). Participants completed the questionnaires and MRI scan at baseline, before treatment began.

Table 1
Demographic characteristics for individuals with social anxiety disorder (SAD) and healthy controls (HC).

	SAD Group	HC Group
Age, *M, SD*	32.74*(8.67)*	32.57*(9.88)*
Female, *n* (%)	16(45.7%)	10(47.6%)
Male, *n* (%)	19(54.3%)	11(52.4%)
Ethnicity, *n* (%)	18(51.4%)	12(57.1%)
Caucasian		
Asian	8(22.9%)	7(33.3%)
Hispanic/Latino	1(2.9%)	–
Filipino	5(14.3%)	–
African American	2(5.7%)	–
Pacific Islander	1(2.9%)	–
More than one ethnicity	–	2(9.5%)
Socioeconomic Status		
Less than $10,000	5(14.3%)	3(14.3%)
$10,000-$25,000	3(8.6%)	–
$25,000-$50,000	6(17.1%)	6(28.6%)
$50,000-$75,000	1(2.9%)	2(9.5%)
$75,000-$100,000	4(11.4%)	1(4.8%)
$100,000 +	9(25.7%)	6(28.6%)

Participants completed the Social Evaluation Task (SET), which has been used in several fMRI studies (Goldin et al., 2014; Ziv, Goldin, Jazaieri, Hahn, & Gross, 2013). Participants were trained to either "just watch" (react condition) or "reframe" (reappraise condition) emotional reactivity to social criticism or praise. The stimuli involved 12-second video clips of actors verbalizing and visually expressing social criticism or social praise (angry/disapproving facial expressions versus happy/approving faces, respectively). There were 16 trials of each condition (react praise, react criticism, and reappraise criticism) across two runs of 513 s each. This was done in a single pseudo-randomized order with no specific condition appearing more than two times in a row.

Each 16.5-second trial consisted of a 1.5-second cue (either "Just Watch" or "Reframe"), a 12-second video stimulus (consisting of a 4.5-second wait period during which the actor silently maintained a neutral facial expression followed by a 7.5-second evaluation period in which the actor verbalized a single social criticism or praise statement while displaying an angry or happy facial expression), and a 3-second period for participants to rate how negative they felt, from 1 (*not at all*) to 5 (*very much*) using a button box. The "Just Watch" (react) and "Reframe" (reappraise) trials were compared to 16 12-second asterisk-counting trials during which participants pressed a button to indicate the number of asterisks on the screen which changed every 3-seconds and varied from 1 to 5 asterisks at a time. The current study focused on the "Just Watch" conditions of criticism and praise compared to the asterisk-counting.

2.3. Measures

2.3.1. Fear of negative evaluation

Participants' levels of FNE were assessed with the Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983). The BFNE is a 12-item self-report questionnaire that assesses fear and distress related to negative evaluation from others, e.g. "I worry about what people think of me even when I know it doesn't make any difference." There are eight straightforwardly worded items, and there is strong evidence to support the greater validity of the sum of the straightforwardly worded items only, omitting the 4 reverse-worded items (Rodebaugh et al., 2004; Weeks et al., 2005). Responses are rated on a 5-point scale from 1 (*not at all characteristic of me)* to 5 (*extremely characteristic of me*). In previous studies, the BFNE has demonstrated strong convergent and discriminant validity (Collins, Westra, Dozois, & Stewart, 2005) and internal consistency (all αs > 0.92) in both undergraduate (Rodebaugh et al., 2004) and clinical (Weeks et al., 2005) samples. The BFNE demonstrated adequate internal consistency in the current sample as well (α = 0.80).

2.3.2. Fear of positive evaluation

Participants' levels of FPE were assessed with the Fear of Positive Evaluation Scale (FPES; Weeks, Heimberg, Rodebaugh et al., 2008; Weeks, Heimberg, Rodebaugh, Goldin, & Gross, 2012). The FPES is a 10-item self-report questionnaire that assesses fear and distress related to positive evaluation from others, e.g. "I am uncomfortable exhibiting my talents to others, even if I think my talents will impress them." Two reverse-scored items are included but are not utilized in calculating the total score. Responses are rated on a 10- point scale from 0 (*not at all true)* to 9 (*very true*). In previous studies, the FPES has demonstrated strong convergent and discriminant validity (Fergus et al., 2009; Weeks, Heimberg, Rodebaugh et al., 2008; Weeks, Heimberg, Rodebaugh, & Norton, et al., 2008) and internal consistency (all αs > 0.80) in both undergraduate (Weeks, Heimberg, Rodebaugh et al., 2008; 2010) and clinical (Fergus et al., 2009; Weeks et al., 2012) samples. The FPES demonstrated adequate internal consistency in the current sample as well (α = 0.80).

2.3.3. Social anxiety symptoms

Participants' levels of social anxiety symptoms were assessed using the Liebowitz Social Anxiety Scale–Self-Report (LSAS-SR; Fresco et al., 2001). The LSAS-SR is a 24-item self-report questionnaire that measures the severity of social anxiety in social interaction situations (11 items), e.g. "Talking to someone in authority," and performance situations (13 items), e.g. "Writing while being observed." Ratings of fear and avoidance are completed on a 4-point Likert scale from 0 (*none* and *never*) to 3 (*severe* and *usually*). In previous studies, the self-report version of the LSAS has shown convergent and discriminant validity and internal consistency (all αs > 0.79) and compared well to the clinician-administered version (Baker, Heinrichs, Kim, & Hofmann, 2002; Fresco et al., 2001). The LSAS-SR demonstrated excellent internal consistency in the current sample as well (α = 0.98).

2.3.4. Depressive symptoms

Participants' levels of depressive symptoms were assessed using the Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996). The BDI-II is a 21-item self-report questionnaire that assesses the severity of current depressive symptoms in the past two weeks, e.g. "I don't have thoughts of killing myself," "I have thoughts of killing myself, but I would not carry them out," or "I would like to kill myself." Responses are rated on a 4-point scale, and participants are asked to choose the answer that best describes themselves. In previous research, the BDI-II has demonstrated convergent and divergent validity and internal consistency (all αs > 0.74) in both clinical (Sprinkle et al., 2002) and non-clinical (Storch, Roberti, & Roth, 2004) samples. The BDI-II demonstrated excellent internal consistency in the current sample as well (α = 0.95).

2.4. Data reduction and analysis

2.4.1. MRI acquisition

A GE 3-T Signa magnet with a T2*-weighted gradient echo spiral-in/out pulse sequence (Glover & Law, 2001) was used to acquire 676 functional volumes across two functional runs from 22 axial slices (repetition time = 1500 ms, echo time = 30 milliseconds, flip angle = 60°, field of view = 22 cm, matrix = 64 × 64, resolution = 3.438 mm^2 × 4.5 mm). A bite-bar and foam padding were used to minimize head-movement. Three-dimensional high-resolution anatomical scans were acquired using fast spin-echo spoiled-grass (.8594^2 × 1.5 mm; field of view = 22 cm, frequency encoding = 256).

2.4.2. fMRI data processing

Preprocessing was performed using the Functional Connectivity (CONN) toolbox in SPM12. The first step was completed using the default pre-processing pipeline in CONN, which included realignment and un-warping, co-registration, segmentation, normalization, and spatial smoothing with a 6 mm kernel. During preprocessing, images were motion-corrected, registered with structural images, and normalized to the standard brain template from the Montreal Neurological Institute (MNI) with voxels resampled at 3mm^3. We examined BOLD signal responses to the "just watch" conditions for three contrasts: criticism vs. control condition, praise vs. control condition, and criticism vs. praise.

2.4.3. fMRI statistical analysis

To examine whole-brain activation, we conducted multiple regressions with self-reported levels of FNE, FPE, social anxiety, and depression as predictors and neural response as the outcome for each of the contrasts using SPM12. Voxel-level significance was set at $p < 0.001$ for whole-brain analyses and cluster-level thresholds were set at $p_{FWE} < .05$.

We also examined the relationship between FNE, FPE, social anxiety, and depression and activation in a set of a priori regions of interests (ROI) selected based on previous research on responses to social evaluation (Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003; Miedl et al., 2016). These ROIs included anatomically defined left (Ke = 24, mm^3 = 1,278) and right (Ke = 20, mm^3 = 1,065) amygdala, left (Ke = 47, mm^3 = 2,503) and right (Ke = 53, mm^3 = 2,822) anterior insula, and left (Ke = 21, mm^3 = 1,118) and right (Ke = 16, mm^3 = 852) posterior insula. The amygdala mask was downloaded from the WFU PickAtlas (Maldjian, Laurienti, Kraft, & Burdette, 2003), and the anterior and posterior insula masks were downloaded from an online atlas of functional ROIs (Shirer, Ryali, Rykhlevskaia, Menon, & Greicius, 2012). Average BOLD signal across all voxels in the ROI were taken from these regions using SPM12. Correlations were run to examine the associations between activation in these ROIs for each of the contrasts and self-reported levels of FNE, FPE, social anxiety, and depression.

Table 2
Descriptive statistics for self-report measures for individuals with social anxiety disorder (SAD) and healthy controls (HC).

Measure	SAD Group Mean *(SD)*	HC Group Mean (*SD*)	*t*
BFNE	32.09 (*5.22*)	15.05 (*4.88*)	12.11**
FPES	41.26 (*14.22*)	15.24(*10.67*)	7.24**
LSAS-SR	82.31 (*17.28*)	16.48(*9.03*)	17.07**
BDI-II	12.63 (*10.00*)	1.95(*2.06*)	4.81**

BFNE = Brief Fear of Negative Evaluation Scale; FPES = Fear of Positive Evaluation Scale; LSAS-SR = Liebowitz Social Anxiety Scale-Self-Report (Clinical Cut-off = 60); BDI-II = Beck Depression Inventory-II (Clinical Cut-off = 14); SDs for each measure are in parentheses.
** $p < .01$.

3. Results

Descriptive statistics for each group are displayed in Table 2. Correlations between self- report measures (FNE, FPE, social anxiety, and depression) are displayed in Table 3.

3.1. Whole-brain results

Whole-brain analyses found no significant associations between BOLD signal responses to criticism versus asterisk counting, praise versus asterisk counting, or criticism versus praise and FNE, FPE, social anxiety symptoms, or depressive symptoms when examining the sample as a whole. In the absence of significant associations, a secondary analysis examined BOLD signal response to criticism and praise versus asterisk counting or criticism versus praise and FNE, FPE, social anxiety symptoms, and depressive symptoms for each group independently. There was a significant negative association between FNE and BOLD signal response to criticism versus praise in the left dorsal anterior cingulate gyrus in healthy controls (MNI coordinates = -17, 18, 41, K_e = 73, mm^3 = 3,887, p_{FWE} = 0.005; see Fig. 1). There were no significant associations between BOLD signal response to criticism and praise versus asterisk counting or criticism versus praise and FNE, FPE, social anxiety symptoms, and depressive symptoms in individuals with SAD.

Table 3
Correlation Matrix between self-report measures.

	BFNE	FPES	LSAS-SR	BDI_II
BFNE				
FPES	.63**			
LSAS-SR	.77**	.70**		
BDI-II	.58**	.38**	.60**	

BFNE = Brief Fear of Negative Evaluation Scale; FPES = Fear of Positive Evaluation Scale; LSAS-SR = Liebowitz Social Anxiety Scale-Self-Report; BDI-II = Beck Depression Inventory-II.
** $p < .01$.

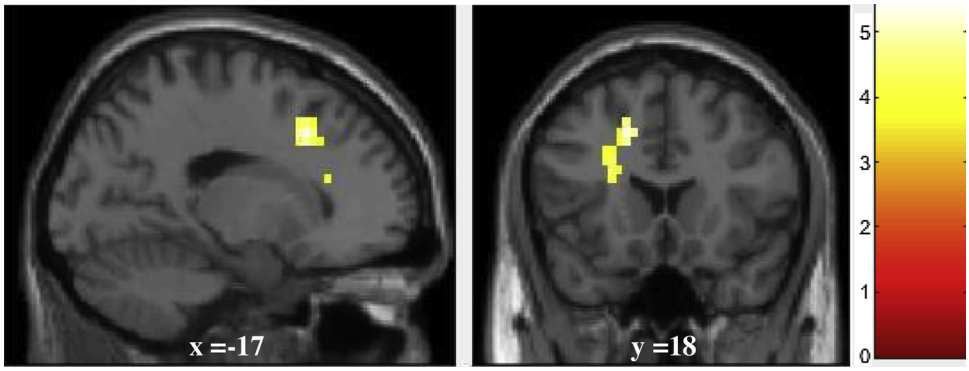

Fig. 1. Results of the criticism > praise contrast, whole-brain FWE-corrected $p < 0.05$.

3.2. ROI results

We also conducted analyses using pre-specified regions of interest. For the contrast of criticism versus asterisk counting, we found significant positive associations between BOLD signal response in the left amygdala and social anxiety symptoms ($r(56) = 0.30, p < 0.05$) and an association between right amygdala and FNE ($r(56) = 0.27, p < 0.05$) in all participants. In addition, social anxiety symptoms ($r(56) = 0.41$, $p < 0.01$) and FNE ($r(56) = 0.27, p < 0.05$) were associated with left anterior insula BOLD signal response to criticism versus asterisk counting.

For the contrast of praise versus asterisk counting, social anxiety symptoms were associated with BOLD signal response in the left anterior insula ($r(56) = 0.39, p < 0.01$) and right anterior insula ($r(56) = 0.29, p < 0.05$), and FNE was associated with BOLD signal response in the left anterior insula ($r(56) = 0.34, p = 0.01$) and right anterior insula ($r(56) = 0.32, p < 0.05$). There were no significant associations between BOLD signal responses and self-reported FPE or depressive symptoms. Additionally, there were no significant associations between BOLD signal responses to criticism versus praise and any of the self-reported symptoms.

As the sample included individuals with and without SAD, it was plausible that associations between BOLD signal and self-report measures may differ across groups. In order to determine whether there were group differences between BOLD signal responses in the ROIs and FNE, FPE, social anxiety, and depression, we compared the correlation coefficients for the associations between activation in the ROIs and clinical measures between the groups (Cohen, Cohen, West, & Aiken, 2003). There were fewer differences in correlations across groups than would be expected due to chance. Thus, the associations between the covariates and neural response in the ROIs did not evince differences across diagnostic groups. See Tables 1–3 in the Appendix in Supplementary material for correlations between neural response in the ROIs and self-reported symptoms by group.

4. Discussion

This study examined the relationship between FNE and FPE and neural response to social criticism and praise. We found that higher levels of FNE were associated with increased BOLD signal response to criticism in the amygdala. A secondary goal was to examine the associations between FNE and FPE and neural response to social evaluation relative to general symptoms of social anxiety and depression. We found that symptoms of social anxiety were associated with increased BOLD signal response to both criticism (in the left amygdala and left anterior insula) and praise (in the left and right anterior insula). There were no significant associations between FPE or depressive symptoms and BOLD signal response to criticism or praise relative to the control condition, or between any of the reported symptoms and BOLD signal response to criticism versus praise.

ROI analyses supported the hypothesis that higher levels of FNE would be associated with increased BOLD signal response to criticism in brain regions associated with emotional processing, including the amygdala. This is consistent with previous research that has implicated the amygdala in the processing of social evaluation (Cunningham et al., 2003; Frewen et al., 2010). ROI analyses did not support an association between FNE and BOLD signal response to criticism in the anterior insula, which is unexpected given previous research implicating the anterior insula in social and emotional processing (Craig, 2009; Gu et al., 2013; Lamm & Singer, 2010; Singer, 2004). In addition, unlike previous research implicating the posterior insula (Miedl et al., 2016; Singer, 2004) and medial frontal cortex (Menon & Uddin, 2010) in responses to social evaluation, the current study did not find associations between activation in these regions and levels of FNE and FPE. As this is only the second study to directly examine the relationship between FNE and FPE and neural response to social evaluation, there are many possible reasons for these unexpected results, including the selected experimental paradigm and alternative strategies, such as disengaging from the task when receiving feedback.

The current study also did not find any associations between FPE and neural response to social evaluation, which differs from previous research. Miedl et al. (2016) found that higher FPE was associated with increased posterior insula activity during positive videos only, while no associations were found between FNE and neural response. The current findings suggest that, in a socially-evaluative context, FNE trumps FPE when they are compared. This is consistent with findings by Barber and Moscovitch (2016) that both high- and low-socially anxious individuals expected an equivalent increase in anxiety at the prospect of negative evaluation and a decrease in their anxiety at the prospect of positive evaluation, relative to their current anxiety level. It is also possible that negative evaluation is more salient to individuals, even when it is general (rather than personally-relevant) feedback, whereas positive evaluation needs to be personally-relevant to elicit a reaction.

In addition, ROI analyses revealed that symptoms of social anxiety were associated with increased neural responses to both criticism and praise relative to the control condition in the amygdala and anterior insula. This is consistent with previous research suggesting that individuals with SAD demonstrate increased BOLD signal responses to social evaluation in social and emotional processing brain regions (Blair et al., 2008, 2011; Heitmann et al., 2014). ROI analyses did not find significant associations between neural responses to social evaluation and symptomatology when depressive symptoms were included in the model. This is inconsistent with previous research suggesting a relationship between FNE, FPE, and depression (Reichenberger et al., 2017, 2015; Wang et al., 2012; Wilson & Rapee, 2005). This could be due to the low average level of depressive symptoms in the sample, which was a function of the study screening procedures that excluded participants with current major depression. Alternatively, it is possible that the positive evaluation was not salient enough to elicit differences in neural response due to the fact that the statements were general,

experimenter- selected statements. Personally relevant positive statements may be necessary to elicit activation in relation to FPE.

The whole-brain analyses showed that healthy controls with higher levels of FNE demonstrated reduced BOLD signal response in the left dorsal anterior cingulate gyrus to criticism compared to praise. However, the whole-brain analyses for the sample as a whole, and the group of individuals with SAD independently, did not reveal any significant associations between neural response and self-reported symptoms. Previous research has suggested that the ACC is involved in attention that regulates cognitive and emotional processing (Bush, Luu, & Posner, 2000), including facilitating increased processing speed in response to conflict (Kanske & Kotz, 2011). Previous research has also suggested that one response to negative emotionality is to disengage or avoid (Garner et al., 2006; Mansell et al., 1999; Weeks et al., 2013; Wieser et al., 2009). Mansell et al. (1999) found that individuals with higher levels of FNE showed an attentional bias away from emotional faces, only under conditions of social-evaluative threat in an unselected undergraduate sample. It is possible that healthy controls with higher levels of FNE utilized attentional control to disengage from criticism relative to praise, resulting in decreased neural response to criticism compared to praise in the cingulate gyrus. However, additional methodologies (e.g., eye tracking) would be needed to examine this possibility.

Fear of evaluation is comprised of two related, but distinct constructs (Gilbert, 2001; Kocijan & Harris, 2016; Reichenberger et al., 2015; Rodebaugh et al., 2012; Weeks, 2015; Weeks, Heimberg, Rodebaugh, Norton et al., 2008; Weeks et al., 2010). The current study found that FNE, but not FPE, was associated with neural response to social feedback. Consistent with previous research (Clark & Wells, 1995; Dryman & Heimberg, 2015; Rapee & Heimberg, 1997; Weeks, Heimberg, Rodebaugh, Norton et al., 2008; Weeks & Howell, 2012), the current results replicate the association between fear of evaluation and social anxiety, both based on self-report measures and the associations between social anxiety and FNE and neural response to criticism and praise in the amygdala and insula. This is also consistent with previous research suggesting that social anxiety was associated with a more unpleasant experience of negative videos and a less positive experience of positive videos based on neural, facial muscular, and experiential indicators (Wiggert et al., 2015).

Although the present study benefits from the inclusion of individuals with and without SAD and relies on a rigorous and robust imaging paradigm with standardized stimuli, the current study has several limitations to consider. First, the control condition in the imaging paradigm relied on non-social cues. This may have limited the conclusions of the current study when comparing positive and negative social evaluation to the non-social, rather than neutral, control condition. It would be beneficial to include a control condition that is social in nature, such as neutral statements and faces to serve as a stronger control condition to criticism and praise. Second, the number of correlations run to examine the relationships between BOLD signal response to social evaluation in each of the contrasts and self-reported symptoms could result in a higher likelihood of type I error. However, we focused on *a priori* regions of interest as the focus of the analyses to reduce the exploratory nature of the work. Third, since the study recruited individuals with and without SAD, there was a wide range of FNE and FPE endorsed, however, middle levels of FNE and FPE were sparsely endorsed, preventing the current study from examining how neural response to social evaluation varies across all levels of FNE and FPE, including moderate levels. Future studies should utilize an unselected sample to assess a full range of fear of evaluation. Fourth, the constructs in the study were measured using self-report questionnaires. Future studies should include both self-reported and clinician-reported levels of FNE, FPE, social anxiety, and depression as these symptoms can be difficult for individuals to accurately report. It would also be beneficial to compare general internalizing symptoms with specific social anxiety or depression symptoms (e.g., Rodebaugh et al., 2017) and how this relates to FNE, FPE, and neural response to social evaluation to further clarify these relationships. In addition, future research should examine these associations in individuals with SAD with a wide range of depressive symptoms. The low levels of depressive symptoms in the current selected sample limited the examination of the relationships between FNE, FPE, social anxiety, and depression and neural response to social evaluation, making it hard to detect any effects of depressive symptoms. Finally, the current study utilized experimenter-selected social praise and criticism. It is possible that these experimenter-selected statements were not salient enough to result in significant differences, particularly for positive feedback. Future studies would benefit from including more self-referent statements that might be more salient to participants. The continuation of this research is imperative for understanding the way in which fear of social evaluation functions as a risk factor for, or maintaining factor of, psychopathology.

Declaration of Competing Interest

Richard Heimberg is the author of the commercially available CBT protocol which was utilized in the randomized controlled trial from which this study was derived. Samantha Birk, Arielle Horenstein, Justin Weeks, Thomas Olino, Philippe Goldin, & James Gross declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.janxdis.2019.102114.

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