

Do neural responses to rejection depend on attachment style? An fMRI study

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Social bonds fulfill the basic human need to belong. Being rejected thwarts this basic need, putting bonds with others at risk. Attachment theory suggests that people satisfy their need to belong through different means. Whereas anxious attachment is associated with craving acceptance and showing vigilance to cues that signal possible rejection, avoidant attachment is associated with discomfort with closeness and using avoidant strategies to regulate one's relationships. Given these different styles by which people satisfy their need to belong (that can operate simultaneously within the same individual), responses to social rejection may differ according to these individual differences in attachment anxiety and avoidance. To test this hypothesis, we used neuroimaging techniques to examine how the degree to which people display each of the two attachment dimensions (anxiety and avoidance) uniquely correlated with their neural activity during a simulated experience of social exclusion. Anxious attachment related to heightened activity in the dorsal anterior cingulate cortex (dACC) and anterior insula, regions previously associated with rejection-related distress. In contrast, avoidant attachment related to less activity in these regions. Findings are discussed in terms of the strategies that individuals with varying attachment styles might use to promote maintenance of social bonds.

Keywords: Social rejection; attachment style; fMRI; social neuroscience; social exclusion

INTRODUCTION

Forming and maintaining positive and lasting bonds with others is a basic human motivation. Like the need for food, water and shelter, the need to belong is deeply rooted in our evolutionary history and has consequences for modern psychological processes. Rejection thwarts the need to belong, leading to widespread impairments in mental and physical health, self-regulation, intelligent thought and higher levels of aggression and self-defeating behavior (House *et al.*, 1988; Williams *et al.*, 2000; Baumeister *et al.*, 2002, 2005; Twenge *et al.*, 2002; Cacioppo *et al.*, 2003; DeWall *et al.*, 2008, 2009; DeWall *et al.*, 2010b). Yet, how people respond to rejection may depend in part on individual differences in how they maintain social bonds—specifically, their attachment anxiety and avoidance. Among people who chronically yearn for others' love and fear that their overtures will be met with rejection, experiencing social rejection may represent an especially painful event. In contrast, people who are generally uncomfortable getting close to others may shield themselves from rejection, resulting in less intense responses.

To date, relatively little research has examined how attachment style influences neural responses to acute social rejection experiences. Using functional magnetic resonance imaging (fMRI), the current study fills this gap in the

literature by examining how attachment anxiety and avoidance uniquely influence responses to social rejection in neural regions that have previously been associated with the distress of social rejection. Understanding how mental representations of attachment figures influence neural responses to social rejection can highlight the close link between personal relationships and physiological processes.

Attachment style

The notion that people have a fundamental desire to gain acceptance and to avoid social rejection forms the basis of attachment theory. Attachment theory was originally developed to elucidate the bonding processes between mothers and infants (Bowlby, 1969/1982) and was later extended to explain adult relationship processes (Hazan and Shaver, 1987; Fraley and Shaver, 2000; Mikulincer and Shaver, 2007, for reviews). According to Bowlby (1969/1982), the purpose of the attachment system is to provide safety by regulating proximity-seeking behavior, which allows for the attainment of care and support from an attachment figure. Over time, these interactions with particular attachment figures are internalized—forming 'internal working models' of one's self-worth in close relationships and how one is likely to be treated by other potential relationship partners. People whose needs for proximity have been met by attachment figures with comfort and support tend to expect these types of responses from other relationship partners. When needs for proximity are discouraged or go unmet, people experience attachment insecurity and turn to other coping strategies.

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Bowlby (1973) noted that people vary in terms of their dispositional tendencies toward anxious and avoidant attachment (Griffin and Bartholomew, 1994; Simpson *et al.*, 1996; Brennan *et al.*, 1998). For example, some people are low in both styles of attachment (i.e. they are securely attached), while others display higher levels of each style. People who display a higher degree of anxious attachment style are thought to ‘hyperactivate’ the attachment system—becoming overly sensitive to signs of rejection or acceptance. They are particularly vigilant for signs that the attachment bond is not as strong as they desire and also opportunities for social connection. They chronically seek to merge themselves with attachment figures while simultaneously fearing that their partner will reject them. In contrast, people who display more of an avoidant attachment style ‘deactivate’ the attachment system—becoming less sensitive to signs of rejection or acceptance. They are less comfortable getting close to others and use avoidant (as opposed to proximity-seeking) strategies to regulate their attachment bonds (Fraley and Shaver, 2000; Mikulincer and Shaver, 2007). Moreover, while people often show greater levels of one attachment style or the other, it is also common for anxious and avoidant attachment to overlap within individuals (Fraley, 2005; Beck and Clark, 2009). Thus, it is possible to investigate the effects of each type of attachment style within the same individuals.

Attachment style and neural responses to social rejection

Like other investigations, the current work examined the independent effects of individuals’ levels of anxious and avoidant attachment on their responses to a socially threatening event (Simpson *et al.*, 1996; Campbell *et al.*, 2005; Gillath *et al.*, 2005; Vrticka *et al.*, 2008). As noted above, people vary in terms of their levels of both anxious and avoidant attachment, making it possible to investigate the effects of each type of attachment style within the same individuals. Indeed, anxious and avoidant attachment tend to overlap within individuals (Fraley, 2005; Beck and Clark, 2009). It makes at least four novel extensions of this prior work. First, the current work examined the effects of anxious and avoidant attachment within the same individuals on responses to social rejection from a ‘potential’ relationship bond instead of an ongoing attachment figure. To the extent that early attachment experiences shape a person’s internal working model of relationships, attachment style may relate not only to an individual’s sensitivity to closeness or rejection in an established attachment relationship, but also to an individual’s sensitivity to closeness or rejection in a ‘potential’ relationship as well (Vorauer *et al.*, 2003; Eastwick and Finkel, 2008). Second, the current work exposed participants to an actual experience of social rejection instead of relying on imagined responses to socially threatening events. Third, participants were not pre-selected on the basis of high

or low anxious or avoidant attachment scores, which enabled us to demonstrate that normative differences in anxious and avoidant attachment within the same individuals could be used to predict neural responses to social rejection. Fourth, whereas prior investigations measured individual differences in attachment style as it pertained to romantic relationships, the current work used a measure of attachment style—the Attachment Style Questionnaire (Feeney *et al.*, 1994)—that assesses general working models of attachment irrespective of relationship type. Therefore, our study was poised to show that normative differences in general working models of attachment predict neural responses to an actual social rejection experience with a potential relationship bond.

How might individual differences in attachment style predict neural responses to social rejection? Previous research examining neural correlates of social rejection have shown that the dorsal anterior cingulate cortex (dACC) and anterior insula are typically activated when individuals are excluded, and more so to the extent that they report feeling distressed by the exclusion (Eisenberger *et al.*, 2003, 2007; DeWall *et al.*, 2010a). Thus, because of its relation to a strong desire for closeness and sensitivity to potential rejection, anxious attachment should predict stronger neural activation to rejection in regions implicated in processing social rejection (i.e. dACC, anterior insula). Indeed, prior work has shown that anxious attachment is associated with more intense behavioral responses to rejection and social conflict (Campbell *et al.*, 2005) and leads to greater negative emotion, somatic symptoms and lower self-esteem in response to imagined rejection (Besser and Priel, 2009). Moreover, fMRI research has shown that when individuals imagine negative attachment-related events (romantic conflict, romantic breakup, partner’s death), *vs* control events (driving alone, shopping with a relationship partner), participants with higher attachment anxiety display greater activation in the anterior cingulate cortex and other emotion-processing regions (Gillath *et al.*, 2005). Moreover, when individuals view angry faces associated with negative feedback, participants higher in attachment anxiety display greater activity in the amygdala (Vrticka *et al.*, 2008), an affective neural region known to process threatening cues, particularly facial expressions (Davis and Whalen, 2001). Thus, it is possible that the responses to social rejection will be especially pronounced among people scoring highly on a measure of anxious attachment, even when the rejection is experienced from a new acquaintance.

Whereas there is reason to expect that attachment anxiety would relate to enhanced neural sensitivity to social rejection, attachment avoidance may relate to reduced neural sensitivity to social rejection (i.e. less activity in dACC and anterior insula). Avoidant attachment is associated with constant regulatory effort to maintain feelings of autonomy and self-sufficiency (Mikulincer and Shaver, 2007). Fraley and

colleagues argue that a core feature of avoidant attachment is minimizing attachment experiences by using strategies that ‘deactivate’ the attachment system (Fraley *et al.*, 2000; Fraley and Brumbaugh, 2007). Specifically, avoidant attachment is associated with minimizing attention to attachment-related events and information. For example, avoidant attachment is associated with poorer memory of attachment-related events on both explicit (Fraley *et al.*, 2000) and implicit (Fraley and Brumbaugh, 2007) measures. These strategies might effectively ‘shield’ people scoring relatively high on avoidant attachment and leave them less fragile to rejection experiences, as indicated by less neural activation in the dACC and anterior insula.

Current research

The current research examined how fluctuations of attachment anxiety and avoidance within the same individuals uniquely related to their neural responses to social rejection. Participants completed a measure of attachment style and then were exposed to a social rejection manipulation while undergoing fMRI. We expected that attachment anxiety would relate to greater neural activity in regions known to play a role in processing social rejection (i.e. dACC, anterior insula). In contrast, we predicted that avoidant attachment would relate to less neural activity in these regions, presumably as a result of sustained regulatory efforts aimed at inhibiting attachment-related events. Given overlap between the anxious and avoidant attachment dimensions (Fraley, 2005; Beck and Clark, 2009), our predictions focused on the unique relationship between each attachment dimension to neural activity in response to social rejection.

METHOD

Participants

Participants included 25 (16 females) healthy, right-handed undergraduates. They reported no history of claustrophobia and were thoroughly screened for metal and other MRI contraindications.¹

Procedures

Approximately 3 weeks before the scan, participants completed an attachment questionnaire (see details below) as part of a battery of measures that were administered for a separate study. On the day of the scan, participants were told they would play a virtual ball-tossing game in the scanner (Cyberball; Williams *et al.*, 2000), which would be played via the internet with two other same-sex participants in other scanners. To enhance the credibility of task, participants

were provided with personal information about the other players (e.g. name, age, hometown, major area of study) so that they could become ‘acquainted’ with them before playing the ball-tossing game. In reality, participants played with a preset computer program and the player information was prepared in advance.

At the beginning of each round of the game, two virtual players appeared in the top left and right corners of the computer screen. An arm was located at the bottom center of the screen, which represented the participant’s hand. After 9 s, the virtual player located in the top left corner began the game by tossing the ball to one of the players. Each time participants received a ball toss, they indicated which of the other players they would like to toss the ball to next by pressing one of two buttons. In the first round of the game, participants were included for the entire duration of the game. In the second round, the other players stopped throwing the ball to the participant after he/she had received three throws. Participants were excluded for the remainder of the game and watched while the other players continued the game without them. Following the scan, participants reported their social distress resulting from this exclusion (see details below). Finally, they were debriefed about the deception involved in the study.

Behavioral measures

Attachment style

Participants completed the Attachment Style Questionnaire (ASQ; Feeney *et al.*, 1994), which assesses the anxious (‘I worry that others won’t care about me as much as I care about them’) and avoidant (‘I prefer to depend on myself rather than other people’) dimensions of attachment. It is a standard and well-validated measure of attachment in adults (Feeney *et al.*, 1994). Moreover, prior work has shown not only that the effects of anxious and avoidant attachment distinct from each other, but are also distinct from general anxiety (Mikulincer *et al.*, 2002). This measure consists of 40 items, which are each answered using a 6-point scale (1 = ‘totally disagree’ to 6 = ‘totally agree’). Items were reverse coded when appropriate and averaged to create a composite score for each attachment dimension (anxious attachment $\alpha = 0.89$; for avoidant attachment $\alpha = 0.87$). Because the current study involved experiencing social rejection and inclusion from a potential attachment bond, the ASQ was used because it assesses general attachment style rather than attachment to specific romantic partners. Three participants did not complete the ASQ; thus, 22 participants (14 females) are included in those analyses that examine the attachment dimensions.

Social distress

Immediately following the scan, participants completed the Need-Threat Scale (NTS; Williams *et al.*, 2000; Van Beest and Williams, 2006), which measures social distress resulting from the exclusion round of the game. The NTS assesses

¹Ten of these participants had been taking daily doses of acetaminophen (the remainder took placebo) for the 3 weeks preceding the scan, as part of a separate study examining effects of acetaminophen vs placebo on neural responses to social exclusion (DeWall *et al.*, 2010a). To ensure that this pre-scan exposure to acetaminophen (or placebo) did not impact the current findings, we controlled for condition (acetaminophen vs placebo) in all behavioral and neuroimaging analyses. There is no overlap between any of the analyses reported in the current report and those reported in DeWall *et al.* (2010a).

20 subjectively experienced consequences of being excluded, including ratings of: self-esteem ('Playing the game made me feel insecure'), belongingness ('I felt like an outsider during the game'), meaningfulness ('I think it was useless that I participated in the game') and control ('I had the feeling that I affected the course of the game'), using a scale ranging from 1 = 'strongly disagree' to 7 = 'strongly agree'. Items were reverse coded when appropriate and were averaged to create a composite score of social distress with high reliability ($\alpha = 0.92$).

fMRI data acquisition

Data were acquired on a 3T Siemens Trio scanner at the University of Kentucky. Functional neuroimaging data were collected during each round of the ball-tossing game using a T2*-weighted gradient echo sequence with the following parameters: 30 ms echo time, 64×64 matrix, 224×224 -mm field of view, 40 3.5-mm axial, slices acquired in interleaved order, 2 s repetition time. These parameters allow whole brain coverage with 3.5 mm cubic voxels. A 3D shim was performed before all EPI image acquisitions.

fMRI data analysis

Neuroimaging data were preprocessed and analyzed using Statistical Parametric Mapping (SPM5; Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). Preprocessing of the neuroimaging data included realignment of images to correct for head motion, normalization of images into a standard stereotactic space defined by the Montreal Neurological Institute and the International Consortium for Brain Mapping and spatial smoothing using an 8 mm Gaussian kernel, full width at half maximum, to increase signal-to-noise ratio.

Each round of the game was modeled as a run with each period of inclusion and exclusion modeled as blocks within the run for a total of two inclusion blocks (one during the first run (60 s) and one during the second run prior to exclusion (42 s) and one exclusion block (60 s). After modeling the ball-tossing game, we calculated linear contrasts for each participant comparing the exclusion block to the inclusion blocks. These individual contrast images were then used in region of interest (ROI) and whole brain regression analyses across all participants.

Region of interest analyses

Based on *a priori* hypotheses regarding the involvement of the dACC and anterior insula in processing social rejection, we utilized anatomically-defined ROI analyses. Thus, we examined differential activity in each ROI during exclusion *vs* inclusion, as well as how this activity related to individuals' distress resulting from exclusion and their anxious and avoidant attachment scores (significance was defined as $P < 0.05$).

ROI extraction was performed using the Marsbar toolbox within SPM. The dACC ROI was anatomically defined as the portion of Brodmann's areas 24 and 32 (as defined by the PickAtlas) posterior to $y = 34$. It was defined as a single mid-line structure, rather than two separate right and left hemispheric portions and to be consistent with standard anatomical definitions. The bilateral anterior insula ROI was anatomically defined as the portion of the insula, as defined by the AAL atlas that is located anterior to $y = 0$. Mean parameter estimates for each participant (that model the amplitude of the BOLD response during exclusion *vs* inclusion) were extracted and averaged across all the voxels in each ROI.

First, we examined the main effect of activity in each ROI during exclusion *vs* inclusion. Next, to examine how each attachment dimension, as well as social distress, related to heightened activity during exclusion *vs* inclusion in each ROI, these parameter estimates were entered as dependent variables in multiple regression analyses in SPSS. Given that participants' scores for anxious attachment and for avoidant attachment were highly correlated ('Results' section), we examined the relationship between each attachment dimension and neural activity in each ROI, controlling for the other attachment dimension². Thus, we examined how anxious attachment related to the differences in neural activity during exclusion *vs* inclusion, controlling for avoidant attachment (and controlling for condition; Note 1) in the dACC and anterior insula ROI, as well as how avoidant attachment related to this difference in neural activity, controlling for anxious attachment, in these ROIs. Given that hypotheses were unidirectional (i.e. more anxious attachment is associated with a greater difference in activity during exclusion compared with inclusion in each ROI), all tests were one-tailed.

Whole brain analyses

To more fully explore the neural regions related to attachment, we supplemented these ROI analyses with whole brain analyses. Again, we performed an initial main effect analysis, in which we compared activity during exclusion *vs* inclusion at each voxel in the brain. Then, we examined correlations between participants' scores for each attachment dimension (controlling for the other attachment dimension), as well as social distress, and their neural activity during exclusion *vs*

²For completeness, we conducted analyses to show the correlations between brain activity and each attachment dimension that did not control for the other attachment dimension. Because of the large overlap between the two dimensions in the current study, however, the zero-order correlations should be interpreted with caution. For ROI analyses, the positive relationships between anxious attachment and the ROIs remained similar, although some effects became marginal (anterior insula: $\beta = 0.31$, $P = 0.07$; dACC: $\beta = 0.26$, $P = 0.12$; right anterior insula: $\beta = 0.36$, $P < 0.05$; left anterior insula: $\beta = 0.24$, $P = 0.14$). In contrast, the negative relationships between avoidant attachment and the ROIs were no longer significant (anterior insula: $\beta = -0.11$, *ns*; dACC: $\beta = -0.08$, *ns*; right anterior insula: $\beta = -0.04$, *ns*; left anterior insula: $\beta = -0.17$, *ns*), although they remained in a negative direction. Effects across the whole brain were no longer significant. Thus, the effects remained in the same direction, but the true effect of each attachment dimension was weakened considerably by not controlling for the large amount of shared variance between the two attachment dimensions in this sample.

inclusion for each voxel in the brain. All whole brain analyses were thresholded at $P < 0.005$, 20 voxels for all *a priori* defined regions (e.g. dACC, anterior insula), while all other regions were examined at a threshold corrected for multiple comparisons (correction for false discovery rate; $P < 0.05$ for magnitude, minimum cluster size of 10 voxels; Lieberman and Cunningham, 2009 for a discussion of thresholding in cases where *a priori* regions are identified). All coordinates are reported in Montreal Neurological Institute (MNI) format.

RESULTS

Descriptive information

On average, participants reported moderate levels of social distress, with NTS scores ranging from 2.10 to 5.80 ($M = 3.99$, $s.d. = 1.00$). There were also a range of scores for each attachment dimension: anxious attachment ranged from 1.46 to 4.00 ($M = 2.90$, $s.d. = 0.86$), and avoidant attachment ranged from 1.53 to 3.80 ($M = 2.97$, $s.d. = 0.66$). Participants' scores for the two attachment dimensions were positively correlated ($r = 0.68$, $P = 0.001$), which replicates prior work showing that the two attachment dimensions relate to each other but can predict theoretically unique responses (Fraleigh, 2005; Beck and Clark, 2009). Thus, in all neuroimaging analyses below we examined the *unique variance* in each dimension of attachment (i.e. 'anxious attachment' refers to the unique effect of anxious attachment after controlling for avoidant attachment, and 'avoidant attachment' refers to the unique effect of avoidant attachment after controlling for anxious attachment). Scores on the attachment dimensions did not significantly relate to self-reported social distress, whether or not the raw dimension score or the unique variance score was examined (anxious attachment without controlling for avoidant attachment: $r = 0.25$, avoidant attachment without controlling for anxious attachment: $r = 0.07$, anxious attachment controlling for avoidant attachment: $r = 0.27$, avoidant attachment controlling for anxious attachment: $r = -0.14$; all P s > 0.21).

Main effect analyses

First, we examined which areas of the brain showed heightened activity during exclusion compared with inclusion, using both ROI and whole brain main effect analyses. As expected, ROI analyses indicated that there was significantly greater activity during exclusion *vs* inclusion in the anterior insula ($t = 2.00$, $P < 0.05$) and this effect held in the right anterior insula ($t = 2.44$, $P < 0.05$) and marginally in the left anterior insula ($t = 1.38$, $P = 0.09$). In contrast, there was no significant difference in the dACC ($t = -0.32$, *ns*). Similarly, whole brain analyses revealed significantly greater activity in the right and left anterior insula during exclusion, while there was no overall difference in dACC activity (Table 1). In addition, this whole brain contrast revealed

Table 1 Regions activated during exclusion *vs* inclusion

Anatomical region	BA		x	y	z	t	k	P-value
Anterior insula	L		-36	24	-3	3.99	233	<0.0005
	R		33	15	-12	4.67	2505	<0.0001
	R		42	30	-3	6.19	2505	<0.0001
VLPFC	45	R	48	27	6	6.43	1346	<0.0001
	47	L	-48	36	-9	4.48	189	<0.0001
VTA/SN		L	-6	-15	-15	6.24	824	<0.0001
DMPFC	8	R	3	42	48	5.52	491	<0.0001
Cuneus	18	L	-9	-93	3	4.53	240	<0.0001
Cerebellum		R	3	-51	-36	4.49	31	<0.0001
		L	-15	-75	-33	4.25	76	<0.0001
Fusiform gyrus	19	R	24	-69	-3	4.40	650	<0.0001
	19	L	-36	-69	-15	3.75	89	<0.0005
MTG	21	R	48	-15	-18	3.87	71	<0.0005
TPJ/pSTS	22	R	54	-45	15	3.77	110	<0.0005
Precuneus	7	L	-12	-63	33	3.45	23	<0.005

Note: Clusters listed were found to be significant in a voxel-wise analysis of the entire brain volume. Regions identified *a priori* (e.g. anterior insula) are listed if they were significant at $P < 0.005$, 20 voxels or greater (k -values listed for these were taken from this thresholding map). Other regions listed were not the primary focus of this investigation but that were still significant after correction for multiple comparisons (k -values listed for these were taken from the thresholding map at $P < 0.05$, 10 voxels, FDR-corrected). BA refers to putative Brodmann's Area; L and R refer to left and right hemispheres; x , y and z refer to MNI coordinates; t refers to the t -score at those coordinates (local maxima); k refers to the number of voxels in each significant cluster. The following abbreviations are used for the names of specific regions: VLPFC, VTA, SN, DMPFC, MTG, TPJ and pSTS.

greater activity in several other regions associated with emotion regulation and social cognition. Table 1 shows a complete list of these activations.

Region of interest regression analyses

Next, we examined how social distress and each attachment style uniquely related to the difference in activity during exclusion *vs* inclusion in the dACC and anterior insula ROIs.

Social distress

Participants' NTS scores were positively associated with activity in both the dACC ($\beta = 0.40$, $P < 0.05$) and bilateral anterior insula ($\beta = 0.41$, $P < 0.05$). This positive relationship was significant for both the right ($\beta = 0.39$, $P < 0.05$) and left ($\beta = 0.40$, $P < 0.05$) anterior insula when each was tested separately.

Attachment style

As expected, anxious attachment showed a unique positive correlation with activity in both the dACC ($\beta = 0.57$, $P < 0.05$) and bilateral anterior insula ($\beta = 0.71$, $P < 0.005$) ROIs (Figure 1A). This unique positive relationship was significant for both the right ($\beta = 0.72$, $P < 0.005$) and left ($\beta = 0.66$, $P < 0.05$) anterior insula when each was tested separately. In contrast, participants' avoidant attachment scores demonstrated a unique negative correlation with activity in both the dACC ($\beta = -0.46$, $P < 0.05$) and bilateral

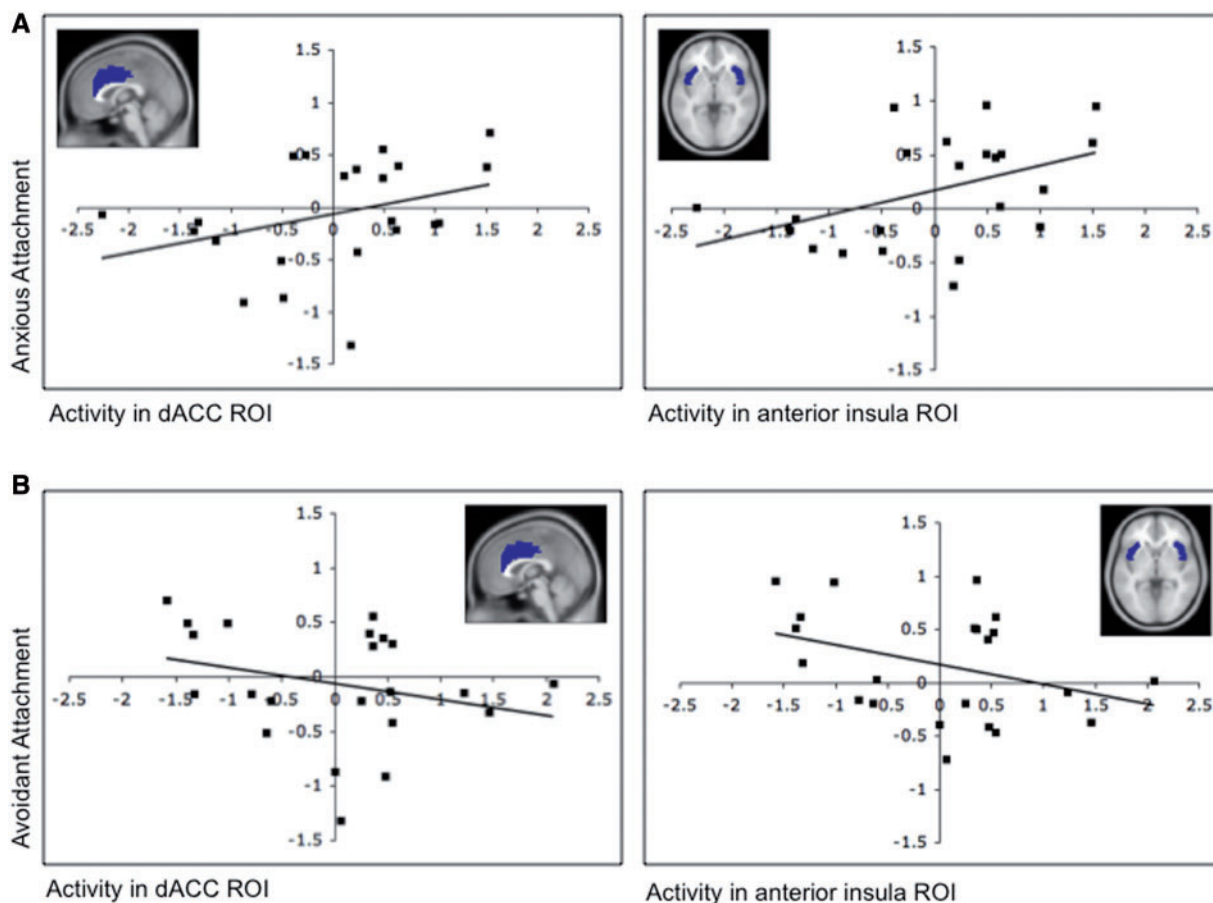


Fig. 1 Associations between the difference in neural activity during exclusion vs inclusion in each ROI (dACC and anterior insula) and each attachment dimension: (A) anxious attachment controlling for avoidant attachment and (B) avoidant attachment controlling for anxious attachment. The values for each attachment dimension represent residualized scores reflecting the unique variance in each attachment dimension, after having removed the variance due to the other dimension (and due to condition; Note 1).

anterior insula ($\beta = -0.59$, $P < 0.05$) ROIs (Figure 1B). This unique negative relationship was significant for both the right ($\beta = -0.53$, $P < 0.05$) and left ($\beta = -0.62$, $P < 0.05$) anterior insula when each was tested separately.³

Whole brain regression analyses

To supplement the ROI analyses, we examined how social distress and attachment style uniquely related to the difference in activity during exclusion vs inclusion across the entire brain.

³Given that social anxiety shares some of the same characteristics as anxious attachment and is associated with slower recovery from social rejection (Zadro *et al.*, 2006; Oaten *et al.*, 2008), we re-examined the relationships between our ROIs and scores on each of our attachment dimensions with social anxiety scores (measured using the widely used and well-validated Social Interaction Anxiety Scale; Mattick and Clarke, 1998; $\alpha = 0.88$; $M = 36.88$, $s.d. = 10.29$ in the current sample) included as an additional covariate. Notably, the relationship between each attachment dimension and activity in the dACC and anterior insula ROIs, after including social anxiety as a covariate, changed very little. Anxious attachment, controlling for avoidant attachment, social anxiety and condition (Note 1), was positively related to activity in the dACC ($r = 0.65$, $P < 0.05$), the bilateral anterior insula ($r = 0.69$, $P < 0.05$) and the right ($r = 0.70$, $P < 0.05$) and left ($r = 0.66$, $P < 0.05$) portions of the anterior insula. Avoidant attachment, controlling for anxious attachment, social anxiety and condition (Note 1), was negatively related to activity in the dACC ($r = -0.43$, $P = 0.07$), the bilateral anterior insula ($r = -0.59$, $P < 0.05$) and the right ($r = -0.54$, $P < 0.05$) and left ($r = -0.62$, $P < 0.05$) portions of the anterior insula. Thus, our main findings were not driven by individual differences in social anxiety.

Social distress

Consistent with ROI analyses, higher scores on the NTS were associated with greater activity during exclusion vs inclusion in the dACC [(-9 12 33), $F(23) = 3.60$, $P < 0.001$, $r = 0.60$, $k = 97$] and right anterior insula [(39 21 9), $F(23) = 3.27$, $P < 0.005$, $r = 0.56$, $k = 20$]. No other regions correlated positively or negatively with NTS scores.

Attachment style

Consistent with ROI analyses, anxious attachment was uniquely associated with greater activity during exclusion vs inclusion in the dACC [(9 18 42), $F(20) = 2.99$, $P < 0.005$, $r = 0.56$, $k = 104$] and right anterior insula [(45 12 3), $F(20) = 3.45$, $P < 0.005$, $r = 0.61$, $k = 393$]. In addition, anxious attachment showed a unique positive correlation with activity during exclusion vs inclusion in the right [(54 33 - 3), $F(20) = 5.63$, $P < 0.0001$, $r = 0.78$, $k = 15$] and left [(-45 33 6), $F(20) = 7.90$, $P < 0.0001$, $r = 0.87$, $k = 20$] ventrolateral prefrontal cortices (VLPFC), which are often associated with emotion regulatory processes (Ochsner and Gross, 2005; Lieberman *et al.*, 2007). No other

regions demonstrated a unique positive or negative correlation with anxious attachment.

Also consistent with the ROI analyses, avoidant attachment was uniquely associated with less activity during exclusion *vs* inclusion in the left anterior insula [$(-30\ 15\ -15)$, $F(20) = 3.59$, $P < 0.001$, $r = 0.63$, $k = 65$]; however, there was no significant unique association with dACC. No other regions correlated positively or negatively with avoidant attachment.

DISCUSSION

To strive to have strong attachment bonds is a core component of human functioning. Rejection thwarts this motivation and a large body of work has shown normative differences between rejected and non-rejected people on a variety of cognitive, emotional and behavioral outcomes. Yet people differ considerably in how they experience and regulate their relationships, making it possible to investigate the role of different types of attachment styles within the same individuals. Whereas some people crave acceptance and are vigilant to signs of potential rejection (i.e. anxious attachment), others are less comfortable getting close to others and use avoidant strategies to regulate their attachment bonds (i.e. avoidant attachment). These differences in attachment style may have direct consequences for neural responses to social rejection. Specifically, anxious attachment may relate to heightened neural responses to social rejection in regions previously associated with social rejection, whereas avoidant attachment people may relate to less activation in these regions.

The current study provided consistent evidence in support of these hypotheses. Anxious attachment was associated with heightened activation in both the dACC and the anterior insula, which are brain regions associated with responses to social rejection (Eisenberger *et al.*, 2003; DeWall *et al.*, 2010a). In contrast, avoidant attachment was associated with dampened neural activation in the dACC and anterior insula. Thus, reactions to social rejection depended in part on individual differences in anxious and avoidant attachment.

The findings dovetail nicely with previous behavioral and neuroimaging findings indicating that anxious attachment is related to greater negative responses to imagined social rejection and interpersonal conflict (Campbell *et al.*, 2005; Gillath *et al.*, 2005; Vrticka *et al.*, 2008; Besser and Priel, 2009). The current work offers a novel extension to this prior work by demonstrating that anxious attachment has theoretically relevant implications for neural responses to experiencing social rejection. Moreover, the findings support prior research showing that avoidant attachment is associated with the deactivation of attachment-relevant information and experiences, thereby enabling people with heightened avoidant concerns to maintain a safe distance from others (Fraley *et al.*, 2000; Fraley and Brumbaugh, 2007). Through this process, people scoring relatively high

on avoidant attachment may be emotionally shielded from socially upsetting events and display less activity in neural regions linked to social rejection as a result. More broadly, the current findings highlight the utility of examining the close interplay between mental representations of attachment bonds and physiological reactions to situations that threaten social connection with others.

As noted earlier, our findings relate to recent research that has investigated the role of individual differences in anxious and avoidant attachment on neural responses to social support or negative feedback, particularly that of Vrticka *et al.* (2008). In that study, participants completed a measure of attachment style and then viewed smiling or angry faces, paired with positive or negative feedback on their task performance. Anxious attachment correlated positively with activation in the left amygdala—another region known to be involved in processing social threat (Davis and Whalen, 2001)—in response to angry faces paired with negative feedback, which converges with our findings that activation in other limbic regions (dACC, anterior insula) to social rejection was heightened among participants scoring high on anxious attachment. In contrast, the Vrticka *et al.* study showed that avoidant attachment correlated negatively with activation in the striatum and ventral tegmental area in response to positive feedback, whereas our study showed no such activations in response to social inclusion (*vs* social rejection). This divergence between the Vrticka *et al.* findings and our results may be due to the fact that the current task focused specifically on social rejection instead of rewarding social interaction. Although the current task involved a social inclusion condition, participants were told that they would be playing a game with two other people and therefore may have not interpreted their inclusion experience as intrinsically positive. Indeed, the creator of the current task has argued that the social inclusion condition can be considered a neutral control condition because it is neither threatening nor rewarding (Williams, 2008). Future research may include manipulations that combine social inclusion with and without indicators of rewarding social interaction (i.e. smiling faces) to directly examine how they differentially influence neural responses according to a person's levels of avoidant attachment.

In addition to this evidence indicating that attachment styles moderate neural responses to social rejection, the current findings also demonstrated that anxious attachment was associated with greater activation in the VLPFC during social rejection compared to social inclusion. Typically, VLPFC activity is associated with distress regulation during social exclusion, and reduced activity in pain/affective regions (Eisenberger *et al.*, 2003). This heightened VLPFC activity, coupled with heightened distress activity, may be indicative of inefficient emotion regulation processes. In other words, people scoring high on anxious attachment engage regions that typically aid in regulation, but they do not display the expected reductions in dACC activity. Future studies will

continue to elucidate the role that prefrontal brain structures play in processing social threats among people who vary in their level of attachment-related anxiety and avoidance.

LIMITATIONS AND FUTURE DIRECTIONS

Overall, the current research offered consistent evidence that neural responses to social rejection depend in part on individual differences in attachment anxiety and avoidance. There are several limitations to the current study that warrant consideration. First, the current study did not examine how attachment-related neural responses to social rejection mapped on to other responses. Future research may examine how neural responses to social rejection among people relatively high in anxious attachment relate to their behavioral distress when discussing an upsetting topic with a relationship partner (Campbell *et al.*, 2005) or how neural responses to social rejection among people relatively high in avoidant attachment relate to their poor memory for details of the people who rejected them (Fraley and Brumbaugh, 2007).

Another limitation is that the social rejection manipulation involved rejection from people with whom a strong attachment bond had not yet developed. Participants learned some information about the confederates who ultimately rejected them, but the strength of this attachment bond was considerably weaker than other bonds participants had with friends, family and potential romantic relationship partners. However, the fact that we found attachment-related differences in neural responses to social rejection from such a weak attachment bond speaks to the strength of the need to belong and how attachment-related processes are relevant even in newly formed attachment bonds (Eastwick and Finkel, 2008).

In addition, although the social rejection task is high in ecological validity, there are several drawbacks of using this task in the fMRI scanner. For example, the order of the inclusion and exclusion blocks are not counterbalanced, as having the exclusion scan come before the inclusion scan would likely change the meaning of the inclusion scan for participants. As a result, it is possible that greater neural activity during the second exclusion block *vs* the previous inclusion blocks is due to expectancy violation (Somerville *et al.*, 2006) or to scanner drift. However, the fact that greater dACC and/or anterior insula activity in this study and previous studies (Eisenberger *et al.*, 2003, 2007) correlated with greater levels of social distress suggests that the difference in neural signal between these two conditions is not due to expectancy violation or scanner drift alone. A final limitation of this design is that long blocks were used, and thus the signal-to-noise ratio was not optimal. However, the fact that neural activity in expected regions correlated with both social distress and attachment style suggests that this was not a significant issue.

Finally, it is worth noting that while our main effect analyses revealed greater activity in the anterior insula during

exclusion *vs* inclusion, there was no indication of differential activity in the dACC. Previous work has shown that social exclusion or other rejection-related stimuli elicit heightened activity in both the dACC and anterior insula (Eisenberger *et al.*, 2003; Kross *et al.*, 2007), although others have shown this main effect in the anterior insula but not in the dACC (Onoda *et al.*, 2009; Masten *et al.*, 2010). In addition, the current study showed that neither anxious nor avoidant attachment correlated with responses on the need threat scale, which limits our ability to make definitive conclusions regarding the role of anxious and avoidant attachment on distress-related responses to social rejection. Thus, while the dACC and anterior insula both appear to be important indices of exclusion-related distress—as evidenced by the positive relationships between activity in these regions and social distress that have been consistently reported in this and prior studies (Eisenberger *et al.*, 2003, 2007; Onoda *et al.*, 2009; Masten *et al.*, 2010), future studies will be useful in further elucidating the specific roles that each of these regions plays in the processing of negative social experiences.

CONCLUDING REMARKS

Social connections bring immense benefits for mental and physical well-being. When those connections crumble through social rejection, people experience significant distress and emotional pain. Some of these responses to rejection can be exacerbated or minimized depending on how people mentally represent their bonds with others. People who relish opportunities for closeness and fear that their overtures will be rejected may have heightened neural responses to social rejection, whereas people who have uneasiness about closeness with others may deactivate the attachment system, resulting in dampened neural responses to social rejection. Thus, our results suggest that exploring the interplay between mental processes and physiological responses is useful in understanding the consequences of social rejection.

Conflict of Interest

None declared.

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