Attachment Avoidance Modulates Neural Response to Masked Facial Emotion

Thomas Suslow,[1]* Harald Kugel,[2] Astrid Veronika Rauch,[1] Udo Dannlowski,[1] Jochen Bauer,[1] Carsten Konrad,[3,4] Volker Arolt,[1] Walter Heindel,[2] and Patricia Ohrmann[1]

[1]*Department of Psychiatry, University of Münster, Münster, Germany*
[2]*Department of Clinical Radiology, University of Münster, Münster, Germany*
[3]*IZKF Research Group 4, IZKF Münster, University of Münster, Münster, Germany*
[4]*Department of Psychiatry and Psychotherapy, University of Marburg, Marburg, Germany*

Abstract: According to recent models of individual differences in attachment organization, a basic dimension of adult attachment is avoidance. Attachment-related avoidance corresponds to tendencies to withdraw from close relationships and to an unwillingness to rely on others. In the formation of attachment orientation during infancy facial emotional interaction plays a central role. There exists an inborn very rapid decoding capacity for facial emotional expression. In this study, functional magnetic resonance imaging was used to examine differences in automatic brain reactivity to facial emotions as a function of attachment avoidance in a sample of 51 healthy adults. Pictures of sad and happy faces (which are approach-related interpersonal signals) were presented masked by neutral faces. The Relationship Scales Questionnaire (RSQ) was used to assess the attachment avoidance. Masked sad faces activated the amygdala, the insula, occipito-temporal areas, and the somatosensory cortices. Independently from trait anxiety, depressivity, and detection performance, attachment avoidance was found to be inversely related to responses of the primary somatosensory cortex (BA 3) to masked sad faces. A low spontaneous responsivity of the primary somatosensory cortex to negative faces could be a correlate of the habitual unwillingness to deal with partners' distress and needs for proximity. The somatosensory cortices are known to be critically involved in the processes of emotional mimicry and simulation which have the potential to increase social affiliation. Our data are consistent with the idea that people who withdraw from close relationships respond spontaneously to a lesser extent to negative interpersonal emotional signals than securely attached individuals. *Hum Brain Mapp 30:3553–3562, 2009.* © 2009 Wiley-Liss, Inc.

Key words: functional magnetic resonance imaging; personality; emotions; somatosensory cortex; social perception

INTRODUCTION

One of the fundamental assumptions of attachment theory is that there are individual differences in the way people organize their feelings, thoughts, and behaviors in social relationships and that those differences are rooted in their representations of experiences in past intimate relationships [e.g., Bowlby, 1969; Hazan and Shaver, 1987; Pietromonaco and Feldman Barrett, 2000]. According to the attachment theory, infants form their internal working models of their selves and others mainly through facial

Thomas Suslow and Harald Kugel contributed equally to this work and should be considered co-first authors.

*Correspondence to: Thomas Suslow, Department of Psychiatry, University of Münster, Albert-Schweitzer-Str. 11, Münster 48149, Germany. E-mail: Thomas.Suslow@ukmuenster.de

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and vocal emotional interactions with primary caregivers. Facial expression is an important social signal of imminent environmental conditions [Ekman, 1972; Fridlund, 1994], and humans have an inborn very rapid encoding and decoding capacity for facial emotional messages [Dimberg, 1997].

According to recent models of individual differences in attachment organization, attachment-related avoidance is a basic dimension that underlies adult attachment [Brennan et al., 1998; Fraley and Shaver, 2000; Griffin and Bartholomew, 1994a]. Attachment-related avoidance corresponds to tendencies to use avoidant versus proximity-seeking strategies to regulate attachment-related behaviors and thoughts. People high on this dimension are unwilling to rely on others and withdraw from close relationships, whereas individuals low on this dimension are relying on others as secure base and feel comfortable opening up to others. Individuals high on attachment avoidance seem to deactivate their attachment behavioral system which is associated with a downregulation of emotions and a low intensity of emotionality [Bartholomew and Horowitz, 1991; Mikulincer and Shaver, 2003; Pietromonaco et al., 2006].

To date, only few studies have examined the cerebral correlates of attachment style. In an fMRI experiment in which participants had to imagine various relationship scenarios, people high on attachment anxiety manifested greater activation in emotion-related brain regions when thinking about negative attachment-related events [Gillath et al., 2005]. Lemche et al. [2006] investigated neural activity during a semantic conceptual priming task and observed that the magnitude of the amygdala response during a separation distress evoking condition was positively correlated with attachment insecurity. Finally, Buchheim et al. [2006] scanned a sample of healthy women during story telling in response to specific attachment pictures. Individuals whose attachment status was disorganized exhibited an increased activation of medial temporal regions compared to those with an organized attachment status. To our knowledge, there exist hitherto no studies that examined brain responses to basic interpersonal signals such as emotional facial expressions as a function of attachment orientation.

Emotion face perception is a complex process that implicates an interactive network of brain regions. Important neural structures underpinning emotion perception from the face are occipito-temporal visual cortical regions (including the fusiform gyrus), the amygdala, the orbitofrontal cortex (including parts of the inferior frontal gyrus), the insula, and the somatosensory cortices [e.g., Adolphs, 2002a,b; Ishai et al., 2005; Kesler-West et al., 2001; Morris et al., 1998; Phillips et al., 2003, 2004; Vuilleumier and Pourtois, 2007]. This network appears to be also involved when faces are presented below the level of conscious awareness [Killgore and Yurgelun-Todd, 2004; Liddell et al., 2005; Nomura et al., 2004; Phillips et al., 2004]. The functional role of the somatosensory cortices in processing emotional expression has received comparably little attention so far. Adolphs et al. [2000] showed that recognizing emotions from facial expressions requires right somatosensory-related cortices (especially the primary somatosensory cortex). This finding is consistent with the idea that recognition of another individual's emotional state is mediated by internally generated somatosensory representations that simulate how the other individual would feel when displaying a certain facial expression.

This study used fMRI at 3T to investigate differences in automatic brain reactivity to biologically anchored social signals (i.e. facial emotions) as a function of attachment-related avoidance. Sad, happy, and neutral facial expressions were administered. Sadness and happiness signal an invitation for social interaction and approach of some sort. Sadness is a signal that the expresser needs to be cared for and is in a submissive position. Happy expressions are invitations to the perceiver to approach the expresser [Knutson, 1996]. By applying faces of persons unknown to study participants, we examined the effect of attachment orientation on the perception of facial emotions in general. The Relationship Scales Questionnaire (RSQ) [Griffin and Bartholomew, 1994b] was used to assess attachment avoidance in a sample of healthy adults. General anxiety (i.e., trait anxiety) and state depressivity were also measured because these mood variables are known to be correlated with attachment avoidance and might be legitimately viewed as offering alternative explanations for our findings [Mikulincer and Shaver, 2003, for a review]. Because attachment avoidance has been found to be related to a low degree of emotionality [Mikulincer and Shaver, 2003; Pietromonaco et al., 2006], it was hypothesized that attachment avoidance should be negatively correlated with the automatic activation of brain systems underlying emotion perception from faces. Thus, it was expected that attachment avoidance is associated with a low neural response to facial expression signaling (a need for) interpersonal approach at an automatic processing level. In this context, special attention was dedicated to the responses of the somatosensory cortices as these brain regions seem to be critically involved in the processes of emotional mimicry and simulation that have the potential to increase social affiliation and interpersonal closeness.

MATERIALS AND METHODS

Participants

Fifty-one right-handed healthy volunteers (23 women; mean age: 28.5 $\pm$ 7.9 year; education: 12.6 $\pm$ 1.2 year) participated in this fMRI study. Participants were selected from a group that responded to a public notice. All subjects had no history of psychiatric or neurological illness, were free of psychotropic medication, had normal or (by contact lenses) corrected-to-normal vision, and were native speakers of German. Subjects were screened for imaging safety concerns, and informed written consent to the study was obtained following the Declaration of Helsinki [World Medical Association, 1991]. The experimental procedure was approved by the institutional ethics committee. Handedness was defined by the Handedness Questionnaire [Raczkowski et al., 1974]. Subjects received a compensation of 20 € for their participation. Women did not differ from men regarding age or education ($P > 0.65$).

Questionnaire Measures

The Relationship Scales Questionnaire (RSQ) [Griffin and Bartholomew, 1994b; Steffanowski et al., 2001] was applied to assess attachment avoidance. The RSQ is designed as a dimensional measure of adult attachment. RSQ scores have shown a relatively high temporal stability in several longitudinal studies with adults so that they seem to measure quite stable traits of personality in adulthood [Scharfe and Bartholomew, 1994; Scharfe and Cole, 2006]. Each questionnaire item was rated on a 1 (*not at all like me*) to 5 (*very much like me*) scale. Respondents had to indicate the extent to which they believe each of the statements best describes their feelings about close relationships. Because standard RSQ scales have low internal consistencies and goodness-of-fit of the original measurement model is low [Kurdek, 2002], responses to the RSQ were aggregated as proposed by Simpson et al. [1992] to create scores for the dimension of attachment-related avoidance. Eight items measured attachment avoidance (e.g., "I am nervous when anyone gets too close to me"). The average avoidance score was 18.7 (SD = 3.9, range: 11–29). Similar to previous research [e.g., Griffin and Bartholomew, 1994a; Kurdek, 2002] the avoidance attachment scale had an acceptable internal consistency estimate of reliability (Cronbach $\alpha = 0.73$). Women did not differ from men in attachment-related avoidance ($P = 0.63$).

The State-Trait-Anxiety Inventory (STAI) [Laux et al., 1981; Spielberger et al., 1970] was administered to measure trait anxiety. The mean STAI trait anxiety score was 34.8 (SD: 8.6, range: 22–56). Cronbach α for the STAI was 0.91. The Beck Depression Inventory (BDI) [Beck and Steer, 1987; Hautzinger et al., 1994] was used to assess the presence of depressive symptoms. The mean BDI score was 3.1 (SD: 3.6, range: 0–13). Cronbach α for the BDI was 0.85.

Stimulus Materials and Procedure

Facial stimuli in the fMRI experiment consisted of grayscale normalized sad, happy, and neutral expressions of 10 individuals [Ekman and Friesen, 1976]. Emotional and neutral faces were used as primes. Neutral faces of the same individuals were applied as masking stimuli. To avoid the identity of prime and mask in the neutral face condition vertically mirrored faces were used as neutral primes. That is, neutral prime faces were produced by mirror-inversion (left to right) of neutral mask faces. Eighty trials were shown: 20 with sad, 20 with happy, 20 with neutral prime faces, and in 20 trials no prime faces were presented. Faces were shown in two fixed random sequences with the restriction of no repetition of an individual and no more than one repetition of a prime condition on consecutive trials. Each trial had duration of 9 s. A fixation cross presented for 800 ms preceded a prime face shown for 33 ms which was followed by a neutral face for 467 ms. A blank screen followed for 7.7 s. In this time period, subjects had to evaluate the briefly shown neutral (mask) face as expressing rather negative or rather positive feelings by pressing one of four buttons (−1.5, −0.5, +0.5, +1.5). During the course of the experiment, subjects lay supine in the MRI scanner with their arms extended at their sides. In each hand, they held a fiber optic response pad with two buttons (the positive or the negative response keys). One half of the sample gave positive responses with the left pad; the other half gave positive responses with the right pad. Judgments and reaction times were registered. Images were presented via projection to the rear end of the scanner (Sharp XG-PC10XE with additional HF shielding). The head position was stabilized with a vacuum head cushion.

fMRI Data Acquisition and Data Analysis

T2* functional data were acquired at a 3 Tesla scanner (Gyroscan Intera 3T, Philips Medical Systems, Best, NL) using a single shot echoplanar sequence with parameters selected to minimize distortion in the region of central interest while retaining adequate signal-to-noise ratio (S/N) and T2* sensitivity. Volumes consisting of 40 axial slices were acquired (matrix: 64 × 64, resolution: 3.5 mm × 3.5 mm × 3.5 mm, TR = 3 s, TE = 30 ms, FA = 90°). Functional imaging data were motion corrected, spatially normalized to standard MNI space (Montreal Neurological Institute) and smoothed (Gaussian kernel, 6 mm FWHM) using Statistical Parametric Mapping (SPM2, http://www.fil.ion.ucl.ac.uk/spm). In addition, T1 weighted inversion recovery and a high resolution T1 weighted 3D sequence (isotropic voxel, 0.5 mm^3) were acquired. An event-related analysis design was used. For each subject, trials were averaged separately for each prime condition (sad face, happy face, neutral face, no face). Thus, the data were reduced to four average trials for each subject. Brain responses to the prime stimulus categories were isolated by convolving a vector of onset times of the emotional and neutral primes and the no-face expression control condition with a synthetic hemodynamic response function. The general linear model was used to model the effects of interest and other confounding effects.

A whole brain analysis using a voxel-wise region of interest approach was conducted to determine brain regions that are activated as a function of attachment avoidance. Activation data (*t* maps) were calculated for each subject in each of the two emotion face conditions (sad and happy) relative to the neutral face control condition. First, one-sample t-tests were performed on activation data for both emotion conditions to determine main effects of emotions. Second, relationships between attachment avoidance as measured by the RSQ and brain activation during processing of masked facial emotion were evaluated using simple regression as implemented in SPM2. Third, multiple regression analysis as implemented in SPM2 was applied to determine the unique variance of attachment avoidance after controlling for trait anxiety, depressivity, and detection performance.

For a priori regions of interest, the significance level in the whole brain analyses was put at $P < 0.01$ (corrected for multiple comparisons across the volume of interest) with clusters defined by at least 10 contiguous voxels of significant response. Regional masks were based on standardized neuroanatomical divisions [Maldjian et al., 2003; Tzourio-Mazoyer et al., 2002]. A priori regions of interest in our whole brain analysis were the amygdala, the fusiform gyrus (including occipital visual processing areas; BAs 19, 37), the superior temporal gyrus (BAs 13, 22, 41, 42), the insula, the primary and secondary sensory cortex (BAs 1, 2, 3; 5, 7, 43), and the orbitofrontal and inferior frontal gyrus (BAs 11 and 47) known to be centrally involved in the (automatic) processing of facial expression of emotions [e.g., Adolphs, 2002a,b; Ishai et al., 2005; Kesler-West et al., 2001; Killgore and Yurgelun-Todd, 2004; Liddell et al., 2005; Morris et al., 1998; Phillips et al., 2003, 2004]. Activations in other brain regions were evaluated at an FDR corrected threshold of $P < 0.05$. Coordinates of significant activations were converted into Talairach and Tournoux [1988] space using the Talairach Daemon [Kochunov and Uecker, 2003]. Participants' characteristic and behavioral data were analyzed using SPSS 15.0.

Detection Task

The detection task was designed to assess awareness of masked emotional faces. After the fMRI experiment a detection task based on the facial stimuli applied in the neuroimaging session was administered outside the scanner. Each of the 40 trials had the following routine: after a fixation cross lasting for 800 ms, a prime face was presented for 33 ms that was directly followed by a neutral target face for 467 ms. Each prime expression (sad, happy, and neutral) and the no-face control condition were presented 10 times in a fixed random order. The instruction was to indicate which of the four conditions was briefly displayed as prime. The chance level for correct answers was 25%. Mean A' values (nonparametric index of sensitivity) were determined for the sad and happy face condition [McNicol, 2004]. For the masked sad face condition, for example, a hit was defined as giving the response "sad" in trials where masked sad faces were shown whereas false alarm was defined as responding with "sad" in trials where masked happy faces, masked neutral faces, or no prime faces were presented.

RESULTS

Questionnaire Measures

There were moderate but significant positive correlations of attachment avoidance with trait anxiety (STAI) and depressivity (BDI) ($r = 0.41$ and $r = 0.36$, $P < 0.01$, respectively).

Detection Task Performance

The mean hit rate for masked sad faces was 18.4% (SD = 18.1) that reflects below chance level performance in our sample (t (50) = −2.58, $P < 0.05$). The mean hit rate for masked happy faces was 42.2% (SD = 33.4%) that indicates an above chance level performance (t (50) = 3.67, $P < 0.01$). Mean A' values (nonparametric index of sensitivity) were 0.52 (SD = 0.08) for the sad face condition and 0.63 (SD = 0.17) for the happy face condition. For both face conditions mean A' values differed significantly from 0.5 (sad faces: t (50) = 2.15, $P < 0.05$; happy faces: t (50) = 5.58, $P < 0.001$). When a stimulus is around Fechner's original idea of a threshold, A' should be about 0.75. The distribution of A' values for the sad face condition in our sample is presented in Figure 1. RSQ avoidance was not associated with the index of sensitivity A'.

Behavioral Performance in the fMRI Experiment

To examine whether evaluative ratings and response times in the fMRI experiment differed as a function of prime condition two repeated measures ANOVAs with one within-subject factor (sad prime, happy prime, neutral prime, and no-face) were calculated. No significant effect

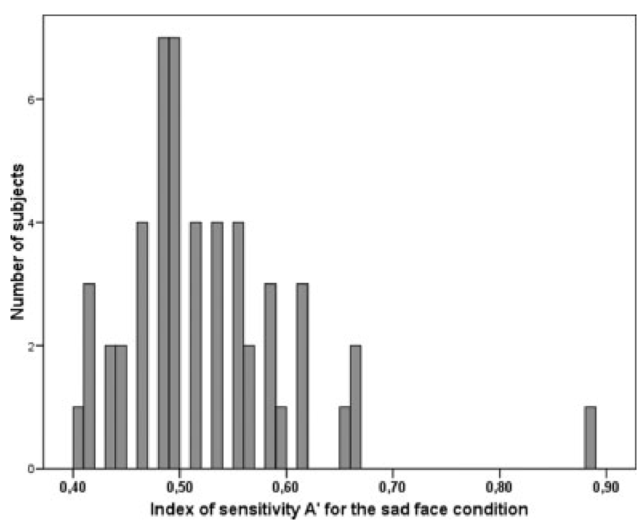

Figure 1.
Distribution of A' values (index of sensitivity) for the masked sad face condition in the detection task.

of prime on evaluative ratings was observed (F (3,48) = 0.29, $P = 0.83$; mean ratings: −0.03 (SD: 0.29) for sad faces, −0.05 (SD: 0.27) for happy faces, −0.04 (SD: 0.26) for neutral faces, and −0.05 (SD: 0.26) for the no-prime condition). There was also no significant effect of prime condition on response speed (F (3,48) = 0.54, $P = 0.66$; mean latencies: 1,434 ms (SD: 330) for sad faces, 1,423 ms (SD: 325) for happy faces, 1,412 ms (SD: 332) for neutral faces, and 1,433 (SD: 325) for the no-prime condition). Attachment avoidance was not correlated with evaluative ratings and response latencies.

Neuroimaging Results

Main effect of masked sad faces

Largely consistent with our hypotheses, there was a significant increase in response to masked sad faces compared to masked neutral faces for many of the selected a priori ROIs (see Table I). Masked presentation of sad expression activated bilaterally the amygdala, the fusiform and lingual gyrus, the middle occipital gyrus, the cuneus, the superior temporal gyrus, and the insula. Furthermore, masked sad faces also activated bilaterally parts of the primary somatosensory cortex (BAs 2, 3) and parts of the right secondary somatosensory cortex (BAs 5, 7).

Main effect of masked happy faces

Masked presentation of happy faces produced less activation than masked presentation of sad faces. Masked happy faces activated the right amygdala, the bilateral fusiform gyrus, the left middle occipital gyrus, the right superior temporal gyrus, and the right insula. Differently from masked sad faces, masked happy expression activated parts of the frontal lobe (see Table II).

Correlations of attachment avoidance with brain responses to masked sad faces

Attachment avoidance was not positively correlated with brain activation in response to masked sad faces. Significant negative correlations were found between attachment avoidance and responses of parts of the primary (BAs 2, 3) and secondary (BAs 5, 7) somatosensory cortices (see Table III).

TABLE I. Brain regions exhibiting significantly increased activation in response to masked sad faces compared to neutral faces

			MNI coordinates				
Brain region	(BA)	Hemisphere	*x*	*y*	*z*	Size	*Z*-score
Amygdala		L	−28	−2	−22	75	4.08
		R	24	−6	−16	53	3.85
Fusiform gyrus	19	L	−22	−62	−16	81	4.37
	19	R	26	−78	−20	13	2.78
Lingual gyrus	19	L	−16	−68	−10	68	4.41
	19	R	12	−56	−2	207	4.11
Middle occipital gyrus	19	L	−44	−82	6	37	4.13
	19	R	42	−70	4	28	4.07
Occipital lobe, cuneus	19	L	−4	−88	26	17	3.61
	19	R	8	−90	24	49	3.23
Superior temporal gyrus	22	L	−54	10	−4	30	2.84
	22	R	62	−2	2	98	4.02
Insula	13	L	−42	16	2	10	2.69
	13	R	40	−10	16	63	3.73
Claustrum		L	−34	−14	10	115	3.65
Postcentral gyrus	2	L	−46	−30	40	29	2.73
	2	R	60	−22	28	11	3.47
	3	L	−20	−34	70	11	3.32
	3	R	32	−34	54	55	3.58
	5	R	30	−44	66	21	2.65
Paracentral lobule	5	R	4	−36	50	41	2.98
Superior temporal lobule	7	R	20	−66	56	10	3.26
Parietal lobe, precuneus	7	L	−14	−72	36	17	2.66
	7	R	10	−82	42	235	3.99

Coordinates of the maximal point of activation and the associated Z-values are shown. The activations in a priori regions of interest are significant at $P < 0.01$ (corrected for search volume); activations in other brain regions were evaluated at an FDR corrected threshold of $P < 0.05$.

TABLE II. Brain regions exhibiting significantly increased activation in response to masked happy faces compared to neutral faces

			MNI coordinates				
Brain region	(BA)	Hemisphere	*x*	*y*	*z*	Size	*Z*-score
Amygdala		R	32	0	−26	63	4.33
Fusiform gyrus	37	L	−36	−50	−20	15	3.17
	37	R	30	−44	−18	14	2.82
Middle occipital gyrus	19	L	−38	−82	2	11	3.10
Superior temporal gyrus	22	R	60	−46	4	15	2.87
Insula	13	R	42	−12	−6	12	2.97
Inferior frontal gyrus	47	R	30	26	−18	20	2.88
Middle frontal gyrus	11	L	−32	40	−18	16	3.02

Coordinates of the maximal point of activation and the associated *Z*-values are shown. The activations in a priori regions of interest are significant at $P < 0.01$ (corrected for search volume); activations in other brain regions were evaluated at an FDR corrected threshold of $P < 0.05$.

Correlations of attachment avoidance with brain responses to masked happy faces

Attachment avoidance was positively related to activation of the bilateral paracentral lobules (BA 5) in response to masked happy faces. Significant negative correlations were found between attachment avoidance and responses of the left inferior frontal gyrus and the left middle temporal gyrus to masked happy facial expression (see Table IV).

Correlation of attachment avoidance with brain responses to masked faces independent from trait anxiety, depressivity, and detection performance

Results of a multiple regression analysis indicate that when controlling for trait anxiety, depressivity, and detection performance (A') attachment avoidance was still significantly inversely correlated with bilateral activation of parts of the primary somatosensory cortex (BA 3), with activation of the left middle frontal gyrus (BA 47), and the left precuneus (BA 7) in response to masked sad facial expression (see Fig. 2 for details).

Correlation of primary sensory cortex activation in response to masked sad faces with behavioral data

Activation of the primary sensory cortex BA 3 in response to masked sad faces was not related to evaluative ratings. However, there was a positive relationship between response of the postcentral gyrus (BA 3) to masked sad faces and the latency difference score sad—neutral (reaction time in the sad face condition minus reaction time in the neutral face condition (M: 22.0 ms, SD: 135.2), peak voxel *xyz*, 22, −34, 58 (MNI coordinates), cluster size: 46, *Z*-score = 3.19, $P < 0.01$ and peak voxel xyz, −50, −18, 48 (MNI coordinates), cluster size: 30, *Z*-score = 3.05, $P < 0.01$). This indicates that activation of the postcentral gyrus (BA 3) was related to longer evaluation latencies for sad compared to neutral faces.

DISCUSSION

In the current fMRI study, automatic reactivity to approach-related facial emotions of negative and positive

TABLE III. Negative correlations of attachment avoidance with brain responses to masked sad faces

			MNI coordinates				
Brain region	(BA)	Hemisphere	*x*	*y*	*z*	Size	*Z*-score
Postcentral gyrus	2	L	−50	−26	32	28	3.21
	2	R	36	−40	62	21	3.60
	3	L	−30	−36	54	15	2.97
	3	R	34	−36	56	122	3.78
Paracentral lobule	5	R	18	−40	60	19	3.26
Parietal lobe, precuneus	7	L	−8	−58	48	10	2.69

Coordinates of the maximal point of activation and the associated *Z*-values are shown. The activations in a priori regions of interest are significant at $P < 0.01$ (corrected for search volume); activations in other brain regions were evaluated at an FDR corrected threshold of $P < 0.05$.

TABLE IV. Correlations of attachment avoidance with brain responses to masked happy faces

			MNI coordinates				
Brain region	(BA)	Hemisphere	*x*	*y*	*z*	Size	Z-score
Positive correlations							
Paracentral lobule	5	L	−2	−40	58	11	2.74
	5	R	2	−40	58	18	2.84
Negative correlations							
Middle temporal gyrus	22	L	−56	−42	2	11	2.70
Inferior frontal gyrus	47	L	−46	18	−4	12	3.04

Coordinates of the maximal point of activation and the associated *Z*-values are shown. The activations in a priori regions of interest are significant at $P < 0.01$ (corrected for search volume); activations in other brain regions were evaluated at an FDR corrected threshold of $P < 0.05$.

valence (i.e., sadness and happiness) was examined as a function of attachment avoidance. Previous research on the brain correlates of attachment orientation did not investigate the responsivity to basic interpersonal signals such as facial emotions. According to attachment theory, differences in attachment orientation are rooted in the representations of past relationship experiences in which facial emotional interaction with primary caregivers is thought to be of central importance [e.g., Bowlby, 1969; Hazan and Shaver, 1987; Stern, 1990]. It is assumed that the resulting internal working models of others are not necessarily accessible to consciousness, as they become habitual and work automatically [Bowlby, 1988; Bretherton and Munholland, 1999].

Our fMRI data indicate that masked sad faces compared to masked neutral faces activate the amygdala, the insula, occipito-temporal areas, and the somatosensory cortices. All of these neural structures are known to be centrally involved in the processing of facial emotions [Adolphs, 2002a,b; Liddell et al., 2005; Phillips et al., 2003, 2004; Vuilleumier and Pourtois, 2007]. In comparison with sad faces, happy faces produced less brain activation even though at least partially in similar cerebral structures (i.e., amygdala, the insula, and occipito-temporal regions). Differently from masked sad faces, masked happy expression activated parts of the frontal lobe, but elicited no response in the somatosensory cortices. In the following, the discussion of the observed relationships of attachment avoidance to brain activation will focus on those brain regions for which a main effect of emotion condition was demonstrated.

Partially confirming our hypothesis, the present results suggest that independently from trait anxiety, depressivity, and detection performance attachment avoidance is inversely related to responses of the primary somatosensory cortex (BA 3) to masked sad faces. That is, individuals high on attachment avoidance tended to exhibit weak somatosensory activations whereas individuals low on this dimension tended to show relatively stronger somatosensory responses at an automatic processing level. Because our detection task was conducted outside the scanner and not all study participants exhibited a detection performance near chance level for masked sad faces, we cannot claim to have assessed subliminal or nonconscious emotion processing. However, insofar as the duration of emotion face presentation was very short (stimulus onset asynchrony: 33 ms) our fMRI experiment should have measured fast evolving neural responses to facial emotions that probably do not require intention or effort. Our data are consistent with the idea that people who rely on others as secure base and feel comfortable opening up to others might spontaneously respond more to negative interpersonal emotional signals. Even though we observed no negative relation between attachment avoidance and responses of the somatosensory cortices to masked happy faces, one should be cautious to prematurely discard such a correlation hypothesis, because the present task did not elicit significant activations in the somatosensory cortices in response to masked happy faces.

The present results suggesting an association between attachment avoidance and responses of the somatosensory cortex to *negative* but not positive faces are, however, consistent with the conclusion of Mikulincer and Shaver [2003] that people using avoidant strategies to regulate social interactions tend to avoid *negative* emotional states that demand attachment-system activation. Sad faces signal that the expresser suffers from disappointment, loss, or depression and needs caring. According to Mikulincer and Shaver [2003] individuals with avoidant attachment strategies are reluctant to confront relational tensions, unwilling to deal with a partner's distress and need for proximity and security. A low responsivity of the somatosensory cortex to masked sad faces could imply a poor automatic elicitation of another individual's negative emotional state [Adolphs et al., 2000]. Individuals high on attachment avoidance are characterized by a deactivation of their attachment behavioral system which leads to a downregulation of interpersonally experienced emotions [Bartholomew and Horowitz, 1991; Pietromonaco et al., 2006]. A reduced automatic generation of somatosensory representations simulating other individuals' negative

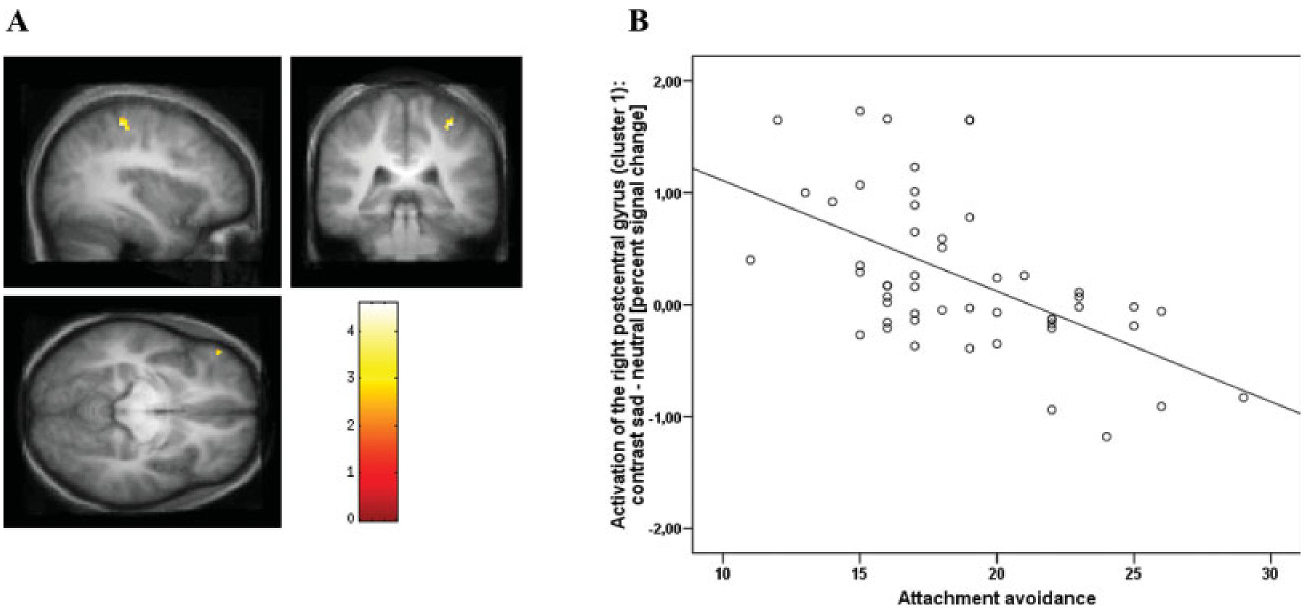

Figure 2.

Negative correlation of attachment avoidance with brain response to masked sad faces after controlling for trait anxiety, depressivity, and detection performance (A') (in the bilateral postcentral gyrus (BA 3) (peak voxel *xyz*, 36, −34, 56 (MNI coordinates), cluster size: 98, *Z*-score = 4.16, $P < 0.01$; peak voxel *xyz*, −46, −22, 42 (MNI coordinates), cluster size: 13, *Z*-score = 2.78, $P < 0.01$), the left middle frontal gyrus (BA 47) (peak voxel *xyz*, −40, 40, −6 (MNI coordinates), cluster size: 17, *Z*-score = 3.37, $P < 0.01$), and the left precuneus (BA 7) (peak voxel *xyz*, −4, −56, 42 (MNI coordinates), cluster size: 13, *Z*-score = 2.77, $P < 0.01$). Blood oxygenation level-dependent responses are superimposed over averaged structural T1 data. Reader's right is subjects' right (**A**). (**B**) The correlation between attachment avoidance and response of the right postcentral gyrus (BA 3) to masked sad faces (activation averaged across the 98 voxels of cluster 1 (peak voxel *xyz*, 36, −34, 56 (MNI coordinates)); $R^2 = 0.37$, controlling for trait anxiety, depressivity, and detection performance (A'), $P < 0.01$. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

emotions could reflect at least in part the neural basis of habitual deactivating strategies of attachment. Such automatic cortical reaction tendencies might be the consequence of caregivers' insensitive responding to the infant's needs and distress in early childhood.

No correlation was observed between somatosensory cortical responses to emotion faces and evaluative ratings. Thus, it could be argued that there is no evidence that activation of the somatosensory cortex in response to emotion faces did elicit (valence-congruent) emotional reactions. In addition, there was no association between attachment avoidance and evaluative ratings. However, it has been noted previously that conscious feelings do not necessarily occur in a subject during facial simulation. The elicited state could be either overt or covert. The reactive circuits engaged in learning early in the development may be engaged covertly in the adult [Adolphs et al., 2000]. We found a positive relationship between postcentral gyrus (BA 3) response to sad faces and the latency difference score (sad minus neutral face condition). That is, it appears that the primary somatosensory cortex is involved in automatic stroop-like interference effects in response to negative facial expression. The stronger the somatosensory activation the more delayed was the evaluative rating which could be due to automatic allocation of processing resources to sad faces.

Interestingly, we found no relationship between amygdala activation and attachment avoidance which appears to contrast with previous results [Lemche et al., 2006]. This inconsistency may be explained by the different types of processes that have been targeted and the different stimulus materials that have been applied. Note that we found a reliable activation of the amygdalae in response to masked sad and happy faces. However, in our study automatic reactions to approach-related facial emotions were examined, whereas controlled processing elicited by threatening or distressing stimuli was investigated in other studies [Gillath et al., 2005; Lemche et al., 2006].

Although we have taken an important first step in the investigation of the neuronal responses to basic facial emotions as a function of attachment avoidance, much work remains to be done. To draw stronger conclusions about the automaticity of neural processes related to attachment style, detection tasks should be performed directly in the scanner in future fMRI studies. By applying faces of persons unknown to study participants we examined the effect of attachment avoidance on the perception of facial emotions in general. Possibly, the observed effects might even be stronger when emotional facial expression of personally significant others ("attachment figures") are presented or individuals with extreme forms of attachment-related avoidance are investigated. Self-report and interview methods such as the Adult Attachment Interview (AAI) show only weak to moderate associations at best [Shaver et al., 2000]. Thus, other self-report measures of attachment avoidance and especially interview methods should be applied in future neuroimaging research.

Our stimulus material was limited to approach-related facial expressions of emotions (i.e., sad and happy faces). Further studies have to clarify whether attachment-related avoidance is also associated with a low neural responsivity to facial expressions of other negative emotions (threat-related such as anger and fear faces or distancing signals such as disgust faces). Attachment anxiety could be positively associated with neural reactivity in fear-related brain systems to threatening facial emotions. Another important objective is the investigation of clearly visible emotion faces to assess controlled or explicit processing of facial expression in relation to attachment strategies. Future neuroimaging studies in this field may also include recording subjects' facial movements and eye gaze during face presentation to further extend our knowledge about the neurobiology of attachment styles and its relations to facial mimicry and contact behavior.

CONCLUSIONS

Our findings show that individual differences in attachment-related avoidance modulate the neural activity in response to negative approach relevant facial expression within the primary somatosensory cortex at an automatic processing level. A low spontaneous responsivity of the primary somatosensory cortex to negative emotion faces could be a correlate of the habitual unwillingness to deal with a partner's distress and needs for proximity. The somatosensory cortices are known to be critically involved in the processes of emotional mimicry and simulation that have the potential to increase social affiliation. Our data are consistent with the idea that people who are unwilling to rely on others respond spontaneously to a lesser extent to negative interpersonal emotional signals than securely attached individuals.

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