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Measuring Attachment Representation in an fMRI Environment: A Pilot Study

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Key Words
Attachment representation · Adult Attachment Projective · Unresolved trauma · Cognitive neuroscience · Functional magnetic resonance imaging

Abstract

This exploratory study is the first to examine the neural correlates of attachment status in adults. The study examined the feasibility of assessing attachment in the functional magnetic resonance imaging (fMRI) environment and investigated theoretically derived hypotheses regarding predicted differences in the brain activation patterns of individuals whose attachment status was organized (resolved) versus disorganized (unresolved) with respect to attachment trauma (e.g., as associated with loss through death, abuse, threat of abandonment). Adult attachment was assessed using the Adult Attachment Projective (AAP), a new projective measure that we thought might be suitable for use in the fMRI environment. This measure was used to obtain a preliminary picture of the neural processes associated with the activation of attachment in 11 healthy female adults. Results are reported from a second-level analysis ($p < 0.001$ uncorrected) and confirm that the AAP is a feasible measure for use in a neuroimaging environment. Cerebral activation during continuous speech yielded results consistent with the literature. Brain activation was demonstrated in expected visual and semantic brain regions. Furthermore, we found that the rate of articulation was positively correlated with the blood oxygenation level-dependent effect and with activation in the right superior temporal gyrus. The results of theoretically derived attachment hypotheses regarding organized versus unresolved/disorganized attachment representations showed no differences at the chosen level of significance when comparing the 'all attachment pictures' effect between both groups (resolved vs. unresolved). More interestingly, we found a significant interaction effect between the sequence of pictures and attachment category. Only the unresolved participants showed increasing activation of medial temporal regions, including the amygdala and the hippocampus, in the course of the AAP task. This pattern was demonstrated especially at the end of the AAP where the pictures are drawn to portray traumatic situations. We interpret these results as confirming our hypothesis, linking unresolved attachment to emotional dysregulation of the attachment system. These results are discussed in relation to assessing attachment in an fMRI environment, attachment theory and future research in this area.

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Introduction

In the present study, we used the Adult Attachment Projective (AAP) [1] to determine if it is a feasible method of assessing attachment in the functional magnetic resonance imaging (fMRI) environment and, if so, to describe individual differences in neurological activation patterns in adults whose attachment status was judged organized versus disorganized. The AAP story narratives have been shown to be valid indicators of attachment status, and the administration procedure was suitable for use with fMRI technology. We measured the neural correlates of word rate and picture presentation while individuals responded to each AAP attachment stimulus. The experiment itself posed two challenges. First, we needed to change the administration procedure so that participants were not guided (i.e. probed) while telling AAP stories in the fMRI apparatus. Therefore, it was not clear whether or not individuals would produce narratives that could be evaluated using the standard AAP coding and classification system [2]. Second, the standard view in fMRI research is for individuals to avoid speaking because head movement may produce fMRI movement and susceptibility artifacts. However, recently published fMRI studies have demonstrated that analysis of fMRI data acquired during speaking is possible, even in schizophrenic patients with severe formal thought disorder [3–5]. In the chapter that follows, we describe the procedure of using the AAP in an fMRI environment, the validity of the AAP classifications and analyses of the fMRI data produced during continuous speech story telling with regard to theoretically derived attachment hypotheses. We hypothesized that unresolved individuals would demonstrate higher activation in limbic regions as compared with individuals with organized attachment (secure, dismissing, preoccupied). The adult unresolved attachment status is conceived in terms of an unintegrated attachment trauma that is ascribed to the underlying dynamics of a severe form of defensive exclusion and dysregulation, termed 'segregated systems' or 'multiple models of attachment' by Bowlby [6–12]. In representative samples with healthy subjects, the proportion of unresolved attachment is about 15–30%, in clinical samples, the proportion is about 70–80% [8].

Typically, adult attachment assessment procedures operationally define unresolved attachment in terms of dysregulation (constriction in adult measures is infrequent compared with children). Dysregulation is the sudden 'unmetabolized' emergence of disorganized thought and emotional dysregulation [13, 14]. It is thought that risk of dysregulation increases as the individual's attachment distress increases (i.e. with increasing activation of the attachment behavioral system) [2]. Thus, we also hypothesized that brain activation patterns in the unresolved group would demonstrate a significant gradual increase in a pattern that paralleled the AAP measurement design – the introduction of increasingly stressful attachment scenes over the course of administration.

Materials and Methods

Participants

The sample for this pilot study comprised 16 healthy, right-handed women recruited from a moderate-sized city in southern Germany. Five of them were not included in the final analysis because of either excessive head movement or reduced number of words produced. The mean age of the remaining 11 subjects was 29.45 years (range 21–43), the mean educational background was 11.09 years in school (range 10–13). Participants had no history of major head trauma, significant medical, neurological or psychiatric illness. Permission for the study was obtained from the local ethical committee (institutional review board). After having given a complete description of the study to the participants, written informed consent was obtained.

The AAP

The AAP [1] assesses adult attachment based on the analysis of narrative responses to a standardized set of eight projective pictures. The AAP pictures are simple line drawings that depict events that according to theory and research activate the attachment system, e.g., illness, solitude, separation and abuse. The subjects are asked to tell a story for each picture. Classification groups are designated through the evaluation of a designated set of narrative dimensions, including narrative style and content and evidence of defensive processing. Individuals whose narratives are dysregulated by frightening, eerie or spectral events are judged unresolved. Individuals whose narratives do not contain these events or demonstrate narrative reorganization are judged organized [2]. The AAP has established convergent validity, test-retest reliability and interjudge reliability [15] in a recent AAP validation study. Convergent validity was established between the AAP and the Adult Attachment Interview [14] – the most widely used validated measure of adult attachment. Convergent validity for classifying individuals as organized versus unresolved was 97% (kappa = 0.88, $p < 0.000$, n = 130). Test-retest reliability (across a 3-month period) was 91% (kappa = 0.79, $p < 0.000$, n = 65). Interjudge reliability has been examined among 2 pairs of independent blind judges. Reliability was 99% (kappa = 0.66, $p < 0.000$, n = 74) and 88% (kappa = 0.70, $p < 0.000$, n = 153).

Experimental Setting

Immediately before scanning, participants were given the standard set of verbal instructions on the AAP. These instructions ask the participant to tell a story about what is going on in the picture, what led up to that scene, what the characters are thinking or feeling, and what might happen next. The participants were also asked to hold their head still while speaking. In order to circumvent the necessity of using AAP probes in the fMRI apparatus, participants were acquainted with the procedure by practicing story telling without probes using two non-AAP neutral pictures (i.e., non-attachment themes such as a horseback riding scene) before entering the scanner. The training procedure was repeated two more times if necessary. During scanning, two additional neutral, non-attachment-related pictures (children are playing in a sandbox, child is riding on a sled with a dog) were presented, followed by the seven standard AAP attachment stimuli (described above). Each picture was preceded by a short version of the standard instruction.

Instructions and pictures were presented with fMRI-compatible video goggles (Resonance Technologies, Northridge, Calif., USA). If participants paused or stopped speaking, no prompting was given. Speech was digitally recorded by means of an fMRI-compatible microphone positioned closely to the mouth and digitally saved with respect to picture onset on a computer (Cool Edit Pro, Syntrillium Software Corp., Phoenix, Ariz., USA). Participants wore customized headphones, which reduced the noise of image acquisition and allowed communication with the experimenter before and after the fMRI procedure (fig. 1).

Immediately before and after scanning, participants were asked to fill out the state form of the State-Trait Anxiety Inventory (STAI) [16] in order to evaluate the emotional state.

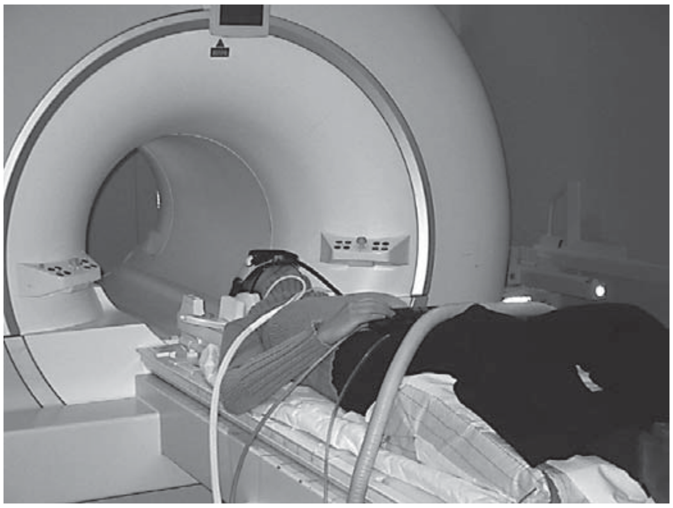

Fig. 1. Subject with video goggles, microphone and headphones in the fMRI-scanner.

Subjective Ratings of Anxiety

In order to control subjective experience, we used the state form of the STAI [16]. Participants were asked to fill out this form before and after the fMRI experiment. This 20-item scale provides an indication of the amount of anxiety the participant felt she experienced at a certain point in time. The STAI is a well-standardized and widely used measure for assessing anxiety. Items are rated on a 4-point Likert scale ranging from not at all to very much. A separate total score for state and trait anxiety is computed. We used a paired-sample t test in order to calculate changes in state anxiety over time.

Word Rates

The frequency of word utterances were counted for each picture and each participant and analyzed using an ANOVA for repeated measures with the factor group (resolved/unresolved) and the picture (1–7).

Linguistic Analysis of Verbal Responses: Attachment Coding

Acoustic noise generated by image acquisition was filtered from the recordings of participants' speech using commercially available software. Participants' speech was transcribed verbatim and translated into English. All transcripts were checked by 2 independent translators (including A.B.), especially all the components of language that are identified in the AAP manual as important to coding (content, defensive processes). Subsequently, narratives were rated by 1 of the authors (C.G.), who was blind to participant identity. Furthermore, all AAP narratives in German language were coded by the first author (A.B.), a certified reliable AAP judge. Interjudge reliability in 11 cases (two raters, two languages) was kappa = 0.814 (91% convergence, p = 0.006) for the groups resolved versus unresolved. Agreement on the 1 divergent case was achieved through consensus and defined as unresolved. In an independent AAP training reliability test set (stories all in English language) of 30 cases, the judges achieved kappa = 0.865 (90% convergence).

Following the AAP coding system [2], spoken discourse, story content and defensive processing were evaluated for a participant's response to each attachment picture. Based on the coding patterns of these AAP dimensions for the seven attachment stories, individuals were classified into one of two main attachment groups, i.e. organized (resolved) versus disorganized (unresolved). According to George and West [2], a specific indication of unresolved attachment status in the AAP is defined as an individual's failure to resolve indicators of segregated system material (i.e. attachment trauma that is disorganized and not integrated) that appears in their stories. This determination process requires the judge to (1) mark the evidence for the segregated system material and (2) evaluate whether or not this material is contained or resolved, based on other evidence in the story. Following the original conceptualization of the segregated system of Bowlby [9], segregated system evidence in AAP stories termed 'markers' is defined as aspects of a story that connote helplessness, fear, failed protection or abandonment (e.g., death, assault, crisis, catastrophe and characters who are helpless, out of control or isolated). In some stories, segregated system markers are evidenced by imagery that has a dissociated, eerie or magical quality. In other cases, the individuals' own traumatic experiences of loss, physical abuse or molestation invade their stories. Once identified, we determined whether or not segregated system markers were resolved. In the AAP, resolution is defined in terms of the individual's ability to draw upon organized, internal working models of attachment to integrate or contain the dysregulated segregated system material expressed in a given story. AAP stories are considered resolved only if they depict characters as capable of drawing on internal or behavioral resources to understand, resolve or try to prevent a threatening situation. Specifically, the individual seeks protection from an attachment figure, draws upon internal resources, takes protective action or demonstrates metacognitive understanding regarding the source of the dysregulation. In the absence of these story elements, the story character continues to be 'haunted' or threatened by feelings of abandonment, fear, helplessness and vulnerability, and the story is judged unresolved.

Image Acquisition

Functional imaging data were acquired with a 1.5-tesla Magnetom Symphony Scanner (Siemens, Erlangen, Germany). TE/TR was 40/2,500 ms, 25 slices; voxel size was 3 × 3 × 5 mm including 1 mm gap. Each picture (shown for 120 s = 48 volumes) was preceded by an instruction (10 s = 4 volumes) followed by a fixation cross (10 s = 4 volumes). Then again, a fixation cross was shown for 15 s (6 volumes) until the next instruction appeared. The whole procedure, including volumes to allow for equilibration effects, lasted about 25 min (598 volumes). For the analysis presented here, the volumes including the first non-attachment-related pictures were discarded so that 462 volumes remained for further analysis. Preprocessing and statistical analysis were carried out with statistical parametric mapping (SPM) 99 (http://www.fil.ion.ucl.ac.uk) executed in MATLAB 6.1 (MathWorks, Natick, Mass., USA) using a general linear model approach [17]. All individual functional images were corrected for motion artifacts by realignment to the first volume of the 462 volumes. All images were spatially normalized to the echo-planar imaging standard template of 3 × 3 × 3 mm voxels using a sinc interpolation and then spatially smoothed with a 9-mm full width at half maximum isotropic Gaussian kernel.

As stated earlier, in order to minimize effects of movement, we exclude the 5 participants who showed excessive movement during the procedure (more than 2 mm within a given picture). Modeling was closely matched to the method used by Kircher et al. [3–5]. Each 120-second AAP picture presentation period was modeled as a regressor ('picture') convolved with the canonical hemodynamic response function of SPM, resulting in seven different picture regressors per participant. Furthermore, the number of words in each of the 20-second epochs during picture presentation was determined from digital recordings in order to model parametric modulation of the picture regressor ('word rate') to account for differences in the amount of words spoken. The six parameters of the realignment procedure (translation and rotation for each dimension x, y, z) were used as covariates of no interest in order to account for putative activation correlated with individual movement. The canonical hemodynamic response function was used as a low-pass filter, and low-frequency drifts were removed via a high-pass filter using low-frequency cosine functions with a cutoff of 240 s.

fMRI Analysis

Individual regionally specific effects of pictures were calculated for each participant using linear contrasts, resulting in a t statistic for every voxel. For each participant, contrasts for single pictures were calculated, i.e. seven contrasts for the attachment pictures ordered 1–7, as well as a contrast for the variable named 'all attachment pictures' (the seven attachment activating pictures). Furthermore, effects of word rate were calculated, again for each picture separately and for all seven pictures together ('word rate'). To account for inter-individual differences, three types of second-level analyses were performed.

First, for the main effect of 'all attachment pictures' and 'word rate' (for all pictures), we calculated two one-sample t tests with all 11 participants. Second, in order to calculate group differences for the 'all attachment pictures' effect, we performed a two-sample t test with the two groups as described above (resolved: n = 6; unresolved: n = 5). In a third analysis, we calculated an ANOVA model on the second level with two groups using subjects as a random factor to evaluate the increasing activation of the attachment system. In this model, seven contrasts were used for each participant, i.e. 'single picture' contrasts for pictures 1–7 yielding 14 regressors (the first seven for the resolved, the second seven for the unresolved group). As the AAP is constructed such that the attachment system should be involved increasingly from picture 1 to 7, we defined the contrast (–3 –2 –1 0 1 2 3 –3 –2 –1 0 1 2 3) and the contrast (3 2 1 0 –1 –2 –3 3 2 1 0 –1 –2 –3) which we labeled 'increasing' and 'decreasing attachment system effect', respectively. Furthermore, we calculated the two interaction effects labeled 'resolved > unresolved increasing attachment system effect' (–3 –2 –1 0 1 2 3 3 2 1 0 –1 –2 –3) and 'unresolved > resolved increasing attachment system effect' (3 2 1 0 –1 –2 –3 –3 –2 –1 0 1 2 3).

In general, we used a threshold of $p < 0.001$ at the voxel and $p < 0.05$ at the cluster level for all second-level analyses. For the second analysis, we also report results from a more liberal threshold of $p < 0.01$ at the voxel and $p < 0.05$ at the cluster level in order to reduce type II error, as our sample size was relatively small for a two-sample t test. Coordinates are given according to the Montreal Neurological Institute template from SPM 99.

Results

Subjective Ratings of Anxiety

The participants' state anxiety levels before the experiment (Time 1) ranged from 29 to 43 (mean 37.63 ± 4.5). The participants' state anxiety levels after the experiment (Time 2) ranged from 28 to 40 (mean 34.72 ± 4.05). The difference between mean values of Time 1 and Time 2 was not significant ($p = 0.243$).

Word Rate

The mean rate of words per picture was 186 (± 65). The mean total number of words for all participants in response to the seven AAP attachment pictures was 1,299 words (range 821–1,910, mean 1,299 ± 56). We did not find an effect of group [$F(1, 9) = 4.25$; $p = 0.07$], an effect of picture [$F(6, 45) = 1.23$; $p = 0.31$] or an interaction effect [$F(6, 54) = 0.99$; $p = 0.44$].

Attachment Analysis of the AAP

All 11 participants successfully told AAP narratives. All narratives were codeable using the standard AAP coding and classification criteria and were similar in content and discourse style to the narratives told in the non-fMRI setting. The attachment classification group distribution of the sample was six resolved and five unresolved.

Functional Imaging

Analysis 1: for the main effect of 'all pictures', we found activation in visual (occipital), motor (precentral cortex, basal ganglia and cerebellum) and language-related areas (temporal cortex), as well as in the anterior

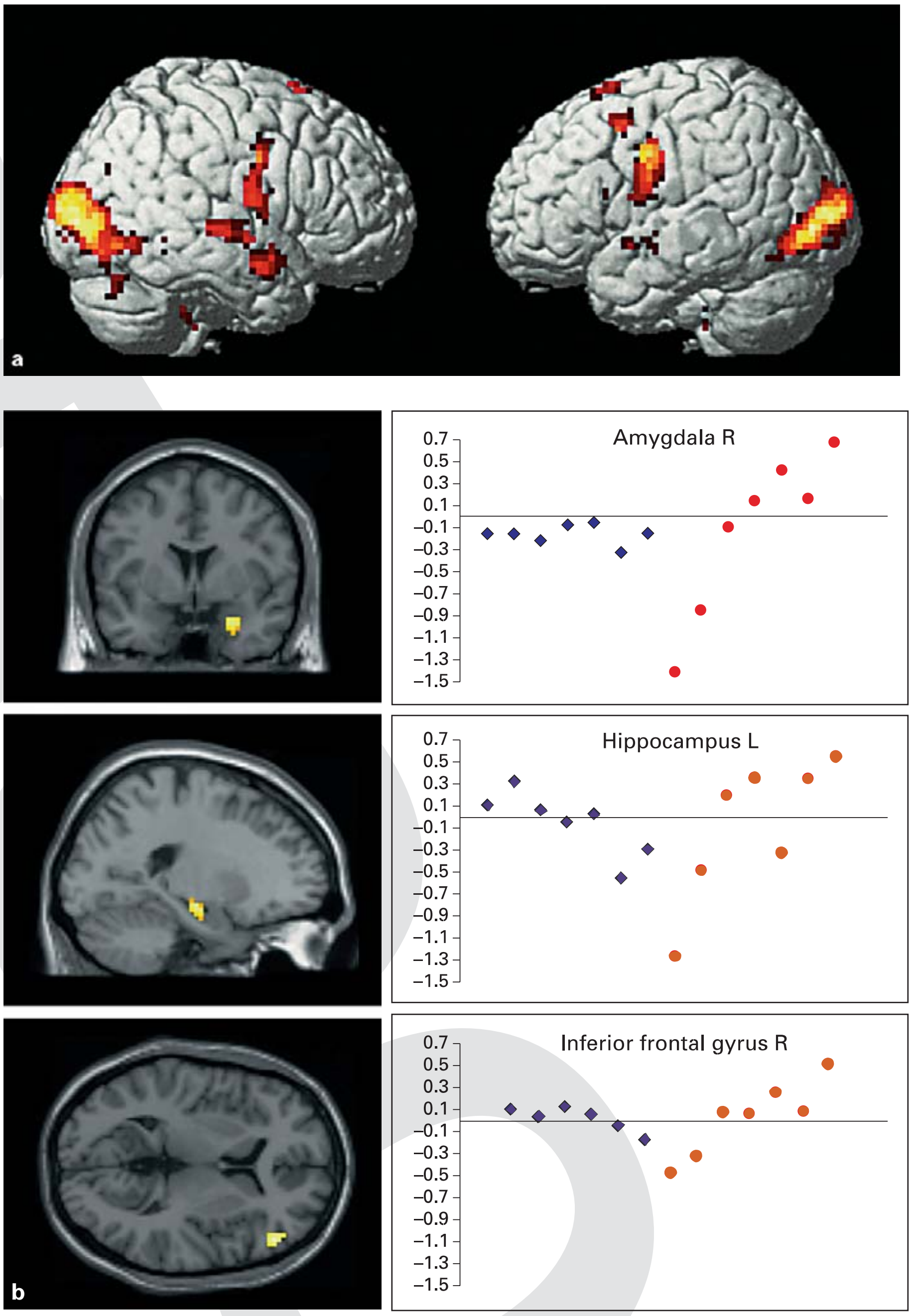

Fig. 2. a Images of statistic parametric mapping for the main effect of picture presentation (‘all pictures’) projected onto a standard T1 template of SPM 99. Z values are color-coded, regions are described by their respective x, y and z coordinates in the standard T1 template in table 1. Activation was found for visual (occipital), motor (precentral cortex, basal ganglia and cerebellum) and language-related areas (temporal cortex), as well as in the anterior cingulate, superior and middle frontal gyrus. **b** Images of statistic parametric mapping for the interaction of groups by increasing attachment system effect projected onto sections of a standard T1 template of SPM 99 (random effects analysis, $p < 0.005$ uncorrected voxel level, $p < 0.05$ extent threshold corrected). Left: activation in the right amygdala, left hippocampus and right inferior frontal gyrus (table 2). Right: plots of parametric responses of the respective regions. Beta-values for each subject of the ‘resolved group’ were colored in blue; red colored dots correspond to each subject of the ‘unresolved group’. A significantly stronger increasing activation in the respective regions can be seen for the unresolved group.

cingulate, superior and middle frontal gyrus (fig. 2a). The coordinates and Z values are given in table 1.

For the main effect of ‘word rate’ (for all pictures), we found the following regions correlating positively with the amount of words spoken: left precentral (x = –51, y = –3, z = 21, Z = 3.78, BA 6) and postcentral (x = –57, y = –6, z = 15, Z = 3.99, BA 4) gyrus, right precentral gyrus (x = 63, y = 0, z = 6, Z = 4.38, BA 6), left (x = –63, y = –24, z = 9, Z = 3.95, BA 42) and right superior temporal gyrus (x = 63, y = –15, z = 0, Z = 4.18, BA 22), as well as left caudate (x = –18, y = 0, z = 18, Z = 5.54) and head of the left caudate nucleus (x = –21, y = –12, z = 9, Z = 3.75).

Analysis 2: when comparing the ‘all attachment pictures’ effect between both groups (resolved vs. unresolved), we found no differences at the chosen level of significance. When lowering the threshold to the more

Table 1. Main effect of picture presentation

Region	Hemi-sphere	Putative BA	x	y	z	Z
Anterior cingulate	R	24	18	0	48	4.63
Superior frontal gyrus	L	6	–6	12	66	4.31
Middle frontal gyrus	L	6	–36	6	51	4.11
Precentral gyrus	R	6	54	–6	12	4.02
Precentral gyrus	L	6	–45	–9	36	4.19
Superior temporal gyrus	R	22	63	–12	0	3.78
Middle temporal gyrus	R	21	54	0	–18	3.92
Middle temporal gyrus	L	21	–57	3	–9	4.04
Occipital cortex	R	18	27	–93	3	5.17
Occipital cortex	L	18	–33	–93	6	4.63
Caudate nucleus	L		–15	6	21	4.26
Globus pallidus	L		–21	–12	–3	3.74
Cerebellar vermis	R		3	–63	–9	4.30
Cerebellar hemisphere	R		18	–50	–21	3.97
Cerebellar hemisphere	L		–18	–50	–18	3.89

Picture presentation (n = 11): one-sample t test, $p < 0.001$ at the voxel, $p < 0.05$ at the cluster level, both uncorrected. x, y, z are coordinates of the Montreal Neurological Institute template in SPM 99, and Z is the Z value of the most significant voxel in the region.

Table 2. Interaction effect for the 'unresolved > resolved increasing activation of the attachment system'

Region	Hemi-sphere	Putative BA	x	y	z	Z
Inferior frontal gyrus	R	45	51	39	3	4.75
Superior temporal gyrus	L	22	–42	–33	–18	3.88
Caudate nucleus	L		–9	21	0	4.73
Amygdala-hippocampal region	L		–21	–15	–12	4.18
Amygdala	R		27	6	–24	4.00

Resolved group (n = 6), unresolved group (n = 5). ANOVA, $p < 0.001$ at the voxel, $p < 0.05$ at the cluster level, both uncorrected. x, y, z are coordinates of the Montreal Neurological Institute-template in SPM 99, and Z is the Z value of the most significant voxel in the region.

liberal level of $p < 0.01$ at the voxel level, we found an effect for the contrast (unresolved > resolved) in the right precentral gyrus (x = 57, y = 0, z = 30, Z = 3.27, BA 6), the left superior temporal gyrus (x = –45, y = –30, z = 18, Z = 3.17, BA 22) and the right occipital cortex (x = 15, y = –93, z = 18, Z = 2.92, BA 18).

Analysis 3: the main 'increasing activation of the attachment system' effect yielded two regions, i.e. the right inferior frontal cortex (x = 51, y = 36, z = 6, Z = 4.73, BA 45) and the left occipital cortex (x = –33, y = –93, z = –3, Z = 3.99, BA 18). There was no main 'decreasing activation of the attachment system'. There was an interaction effect for the 'unresolved > resolved increasing activation of attachment system' showing a significantly stronger increasing activation in the right inferior frontal cortex, the left superior temporal gyrus, head of the left caudate nucleus and in the bilateral medial temporal lobe regions for the unresolved group (table 2, fig. 2b).

Discussion

Adult Attachment Measure Applied in an fMRI Environment

The first goal of this study was to determine the feasibility of using the AAP in a neuroimaging context. Our results demonstrate that the AAP can be conducted in an fMRI environment, that the participants' narratives can be coded using the standardized AAP classification and coding manual and that it is possible to analyze fMRI data during continuous speech in a relevant portion of participants. All of the participants in this sample completed the experiment. Participants were comfortable with the task and did not feel anxious or emotionally overwhelmed before or after the experiment due to the fMRI environment. State anxiety values of our 11 participants after the experiment even showed a trend to decreased state anxiety, although the statistical analysis of this pattern showed that the drop was not significant. The AAP narratives produced by our participants resembled those usually obtained in the standard administration environment. The number of words produced for all seven AAP narratives was comparable in length with the AAP narratives obtained under non-scanning conditions. The examination of a random sample of 20 cases from an English-speaking AAP validity study sample showed that the average number of words produced was 1,251 as compared with 1,299 in this sub-sample (German language transcripts translated into English). Thus, the important modified administration procedure we used, i.e. participants practicing the AAP story telling format prior to entering the fMRI apparatus, was a successful procedural substitute for the standard probing administration format. The transcribed narratives in this study were coded using the standard AAP coding and classification manual. All transcripts were classifiable, and interjudge reliability was high. In this sample, 6 subjects were rated as resolved and 5 as unresolved. Due to the small sample size, this distribution is not regarded as representative of the general population of adults [1], nor was it necessary for the goals of this study to obtain a representative attachment sample. In order to measure brain activity comparing resolved versus unresolved attachment groups, the fairly equal distribution of participants (6 vs. 5) was appropriate. For external validation, we also administered the Adult Attachment Interview [13] in these subjects in order to control whether attachment classifications with a comparable instrument will be the same. The convergence for classifying individuals as organized versus unresolved was kappa = 1.0 ($p < 0.000$). This indicates that measuring attachment representation with the modified AAP procedure was achieving valid results not disturbed by the fMRI environment.

Three of these excluded participants were classified as resolved, 2 were classified as unresolved. With respect to attachment, these participants were not different from those included in the study. Third, we included the realignment parameters resulting from the movement correction procedure as implemented in SPM 99 into single-subject analysis. Thus, movement-related activity was modeled as a covariate of no interest. Artifacts can also be introduced by air volume changes in the pharynx during phonation. However, at 1.5 T, when overt responses are continuous such as in our study, these effects on grouped data are likely to be small, except in areas close to the orbital frontal cortex. Areas of significant activation in our study were not detected in the orbitofrontal cortex. Further, raw fMRI images were inspected visually, and no excessive susceptibility artifacts were present. fMRI is also associated with significant scanner noise, but all our subjects reported that they were able to hear themselves speaking during the tasks. To rule out handedness and sex as potential confounders, we only included right-handed female participants [18].

Neural Correlates of Adult Attachment Patterns

The second goal of this study was to obtain a preliminary picture of the neural processes associated with activation of the attachment system in response to visual attachment stimuli, and especially those processes related to attachment dysregulation. We found a main effect of AAP picture presentation ('all attachment pictures') in brain regions in which they would be expected. Visual information processing is performed in the occipital cortex. Activations of the precentral gyrus as well as the premotor cortex are associated with the motor aspects of speaking. The precentral activation was found in the region were the face region is located according to the somatotopy of the primary sensorimotor cortex [19]. Language-related areas found were the temporal cortices on both sides, which have been associated with semantic retrieval processes [4].

Across all subjects, calculating the effect of word rate, we found the precentral cortex and the superior temporal gyrus bilaterally correlated with the rate of words spoken. In a design in which individuals gave verbal responses to Rorschach inkblots, Kircher et al. [3–5] found that the rate of articulation was positively correlated with activation in the left superior temporal (BA 22) as well as the supramarginal (BA 39/40) gyri. In formally thought-disordered subjects with schizophrenia, a superior temporal activation was found by the same group in the right superior temporal cortex [3–5]. We did not find any evidence in the narratives that our participants were formally thought disordered. The paradigms differed insofar as Kircher et al. [3] asked their subjects to speak freely about the inkblots whatever came to the subjects' minds, whereas the task in our experiment was to tell a story. The underlying implication of the AAP is that the story has a basic organization form that includes a beginning, middle and end. This may explain why the results were not exactly the same regarding lateralization. Further, a number of imaging studies have shown the involvement of the right superior temporal gyrus in higher language functions and in particular in context processing, which is consistent with our results [20–22].

The second analysis examined attachment-specific activations. We hypothesized that activation of limbic areas would be greater in participants who were judged unresolved as compared with those whose attachment classifications were resolved. In the direct comparison of the 'all attachment pictures' analysis we could not demonstrate such differences, neither with the a priori chosen threshold nor with the more liberal threshold. However, this lack of differences might well be accounted for by the small number of subjects involved in this pilot study.

The third analysis also examined attachment-specific activations. It was modeled along the logic of the design of the AAP measure. According to this logic, the picture presentation sequence increasingly activates the attachment system. Calculated over both groups, resolved and unresolved, we found increasing activation of the right inferior frontal cortex. This brain activation pattern is thought to be related to the control processes involved in emotion regulation. It has been shown that the inferior prefrontal cortex is involved in emotion regulation processes like suppression of unwanted emotion and reappraising highly emotional scenes in unemotional terms [23, 24]. Even more interestingly, there was a significant interaction effect between sequence of pictures and attachment category. Only the unresolved subjects showed increasing activation of medial temporal regions including the amygdala and the hippocampus. The amygdala is central to the processing of emotion, mainly in perception and processing of negative emotions like fear [25, 26], whereas the hippocampus is a critical brain structure for the retrieval of autobiographic memory [27]. Amygdala activation was found for the retrieval of autobiographic material compared with fictitious memory [28] and is thought to be part of a defense response control network [29]. Moreover, activation of the amygdala and lateral prefrontal cortex has been reported for the ecphory of sad compared with happy autobiographical memories [30].

We interpret these results as a confirmation of our a priori hypothesis linking unresolved attachment to dysregulation of the attachment system. We predicted and found that threatening situations in the AAP were emotionally more involving for the unresolved participants than for participants judged resolved. This pattern was demonstrated especially at the end of the AAP where the pictures were drawn to portray traumatic situations. Thus, activation of the amygdala and hippocampal regions may result from a potential reactivation of 'unresolved' traumatic or negatively valenced autobiographical material associated with the AAP pictures. A more general explanation for this finding might be that subjects classified as unresolved may experience more stress during the AAP procedure than subjects classified as resolved, referring to the psychobiological results on infant disorganization [31, 32].

There are several limitations to our study. First, the sample size is small, which suggests caution in the interpretation of our results regarding the attachment-related phenomena. Second, although the number of words per picture did not differ between groups, not all participants spoke for the entire 120 s of time allotted for the picture stimulus response. This was not taken into account by our modeling. Third, there is the general problem that overt speech is inevitably contaminated by small movement. Although we used all available measures to control for movement, future studies should involve more participants that could then allow for more sophisticated modeling, e.g., modeling every word in every picture of every subject.

In summary, we have demonstrated that the AAP is a feasible measure to assess attachment representation in an fMRI setting. The scanner noise and the unusual environment did not lead to interruptions or dropouts. The AAP narratives obtained can be coded along the standard manual [1, 2], and cerebral activation during continuous speech can be analyzed yielding results which are consistent with the literature. Our results are comparable with those of Kircher et al. [3–5], showing a positive correlation of amount of speech with lateral temporal activation and primary motor cortex activation as a function of word production rate. Moreover, we could demonstrate attachment-specific findings with unresolved subjects showing significantly more activation of limbic areas in the course of the AAP. This is an ongoing study. Based on the presented results, we will continue this research to investigate the neural correlates of attachment patterns relating to special linguistic and content markers of the AAP, especially comparing patients with a borderline personality disorder with non-patient healthy controls using our fMRI-adapted attachment paradigm.

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