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The Precuneus and the Insula in Self-Attributional Processes

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ABSTRACT

Attributions are constantly assigned in everyday life. A well-known phenomenon is the self-serving bias: People's tendency to attribute positive events to internal causes (themselves) and negative events to external causes (other persons/circumstances). Here, we investigated the neural correlates of cognitive processes implicated in self-serving attributions using social situations differing in their emotional salience.

We administered an attributional bias task during fMRI scanning in a large sample of healthy subjects (n = 71). Eighty sentences describing positive or negative social situations were presented. Subjects decided via button press whether the situation had been caused by themselves or by the other person involved.

Comparing positive with negative sentences revealed activations of the bilateral posterior cingulate cortex (PCC). Self-attribution correlated with an activation of the posterior portion of the precuneus. Self-attributed positive versus negative sentences showed an activation of the anterior portion of the precuneus. Self-attributed negative versus positive sentences demonstrated an activation of the bilateral insular cortex. Significant activations are reported for a statistical threshold of p ≤ .001 uncorrected. In addition, the comparison of our fMRI task with the Internal, Personal and Situational Attributions Questionnaire, Revised German Version (IPSAQ-R) demonstrated convergent validity.

Our findings suggest that the precuneus and the PCC are involved in the evaluation of social events with particular regional specificity: the PCC is activated during emotional evaluation, the posterior precuneus during attributional evaluation, and the anterior precuneus during self-serving processes. Furthermore, we assume the insula activation as a correlate of awareness of personal agency in negative situations.

1. Introduction

People evaluate their own and other's behavior seeking ('attributing') causes for the occurrence of social events. The cognitive and emotional processes involved in these ascriptions are the focus of neuroscientific research on attributional patterns, which is based on the assumptions of the Attribution Theory. Research in this field is diverse and findings are inconsistent. Therefore, the main goal of our study was to extend the knowledge about self-attribution processes by giving a detailed overview of current and classical literature, by using a large sample size, and by providing a careful analysis and interpretation of our results.

The origins of Attribution Theory date back to the 1940s and 50s when Heider authored his seminal treatises "Social perception and phenomenal causality" (1944) and "The Psychology of Interpersonal Relations" (1958). Heider divided people's explanations ('attributions') for the occurrence of different events into two types of causes: personal and environmental. Subsequent enhancements, systematizations and reinterpretations of the Attribution Theory were elaborated by Kelley (1967), Jones and Davis (1966), and later by Weiner (1974; 1986).Today there are numerous models on attributional processes, which can be summarized under the generic term Attribution Theory.

In this sense, Försteling defines Attribution Theory as a group of theories on "how common sense operates" (Försterling, 2001, p. 3) focusing on "the processes that make our everyday circumstances understandable, predictable, and controllable" and which findings are "applicable to a wide area of domains such as achievement, love, health, friendship, and pathology" (Försterling, 2001, p. 4). Attribution Theory is a cognitive approach in psychology, accordingly research of attribution focuses on thoughts or cognitions concerning "how individuals select, process, store, recall, and evaluate (causally relevant) information and how the information is then used to draw causal inferences" (Försterling, 2001, p. 10).

Research in the field of attribution theory revealed that attributions are susceptible to errors and biases (Försterling, 2001), such as attribution errors (Ross, 1977), attribution asymmetry (Frieze & Weiner, 1971) or the self-serving bias (Hastorf, Schneider, & Polefka, 1970). The so-called

'attributional bias' is an umbrella term for different psychological phenomena, which underlie the process of attributing responsibility/causation for various events or actions to different causes. Research on the phenomena of 'attributional biases' has a long tradition in social psychology. It has been investigated in different ways: in terms of ego-defense and need for control (Cialdini, Braver, & Lewis, 1974; Kelley, 1967, 1987; Luginbuhl, Crowe, & Kahan, 1975), actor observer differences (Jones & Nisbett, 1987; Mischel, 1968; Ross, 1977), primacy effects (Kanouse, 1971) and responsibility for accidents (Vidmar & Crinklaw, 1974; Walster, 1966, 1967) (Fischhoff, 1976). Heider remarked that the process of attribution is influenced by personal needs, feelings and emotions of the one who attributes (Heider, 1958). Jones and Davis (1966) took a closer look on this personal involvement as a component of the attribution process and considered two manifestations: the hedonic relevance and the variable of personalism (Shaver, 1975). Kelley (1967) expanded this ambit and distinguished between self-attributions and attributions to others as well as the environmental context. This has led to different understandings of attributional biases. One aspect is the self-serving bias (SSB). The basic assumption here is that people tend to attribute events with positive outcomes to internal causes (themselves) and events with negative outcomes to external causes (the other person/s involved or the situation) (Hastorf et al., 1970; Kelley, 1973; for a summary see: Zuckerman, 1979). Hewstone (1989) points out two components of SSB: the 'self-enhancing bias' (tendency to attribute success rather to internal causes) and the 'self-protecting bias' (tendency to attribute failure rather to external causes). In context of a certain blurring of concepts in current research it is important to note at this point – as Hewstone (1989) did – that the research about SSB involves common-sense explanations and that the attribution of causes to persons in this context is not a legal, moral or philosophical issue. Thus, it has to be distinguished clearly between the concepts of blame, cause and responsibility (Hewstone, 1989).

More recently, there have been several neuroscientific studies investigating the neural correlates of the 'attributional bias' using different techniques. Blackwood et al. (2003), Seidel et al. (2010), and Harris et al. (2005) employed fMRI (functional magnetic resonance imaging), and Krusemark et al.

(2008) EEG (electroencephalography). Blackwood et al. (2003) examined the neural correlates of the self-serving bias with an attributional decision task analogous to the internal, personal and situational attributions questionnaire (IPSAQ, Kinderman & Bentall, 1996). Participants had to decide whether the ten positive and ten negative statements describing social situations taken from the IPSAQ were caused by themselves, by the other person involved or by the situation. The authors found that self-responsibility attributions, in contrast to personal and situational attributions were related to activations in the left lateral cerebellar hemisphere (lobule V), bilateral dorsal premotor cortex, and right lingual gyrus. Self-serving attributions were related to bilateral caudate nucleus activations, whereas non-self-serving attributions (i.e. external attribution of positive events and internal attribution of negative events) were associated with activations in the left lateral orbitofrontal cortex, right angular gyrus (AG), and right middle temporal gyrus (mTG). The authors concluded that the self-serving bias is mediated by the dorsal striatum, which is as well implicated in motivated behavior. Furthermore, they suggested that self-responsibility as social cognition of higher order is related to simpler internal models of goal-directed action as reflected by activation of the bilateral premotor cortex and the cerebellum (regions substantially implicated in action simulation) (Blackwood et al., 2003). Harris et al. (2005) used an attribution paradigm, in which participants had to make an attributional decision about the causes of several social events after seeing additional information about consensus, distinctiveness, and consistency of the described event. The authors found dispositional attributions (i.e. attributions of perceived behavior to the internal states of persons like unique attitudes, individual personality, idiosyncratic intent) to be related to activations mainly in the right superior temporal sulcus (STS), the bilateral medial prefrontal cortex (MPFC), the right mTG and the right precuneus. They concluded that there are common regions underlying social cognition – such as theory of mind (ToM) and attribution tasks – and specific neural activation patterns in unique dispositional attributions (Harris et al., 2005). The event-related potential study from Krusemark et al. (2008) used a facial working memory task, in which participants got false (success or failure) feedback. Non-self-serving attributions were associated with activity in the left

MPFC. Together with the results from previous findings (Amodio & Frith, 2006; Ochsner et al., 2004; Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004) these results were interpreted as unbiased attributions requiring greater self-control (Krusemark et al., 2008). Seidel et al. (2010) used a social situation paradigm to analyze the neural correlates of internal and external attribution in social events and of the self-serving bias. Participants had to decide, whether the presented positive and negative social situations were mainly caused by themselves, the other person involved or the situation. Internal contrasted with external attributions revealed activations along the right temporo-parietal junction (TPJ), in the right supramarginal gyrus and the superior temporal gyrus (STG) bilaterally. The reverse contrast (external vs. internal attributions) revealed activations of the left parieto-frontal network involving the lateral and medial parietal areas and the superior frontal regions with activations in the left and right precuneus, the right cuneus and along the left TPJ including activations in the left AG, left mTG, the left superior, middle, and superior medial frontal gyrus. Bilateral dorsal anterior cingulate cortex activation (ACC) correlated with the self-serving bias. These results support the assumption that a fronto-temporo-parietal network is involved in differentiating self and external responsibility, whereas the correlation of the activation in the dorsal ACC and in the dorsal striatum with the self-serving bias is understood as link to its rewarding value (Seidel et al., 2010).

Additionally, there have been further studies using different tasks, but examining the same underlying cognitive phenomena. E.g., Moran et al. (2006) used fMRI to investigate the dissociation between cognitive and affective components in self-reflective processes. The authors provided a task in which subjects had to judge the self-descriptiveness of favorable and unfavorable trait words. They reported that activity in MPFC and PCC differs in context of increasing self-relevance regardless the valence of the stimuli, whereas activity of the ventral ACC was dependent on valence.

Beer and Hughes (2010) investigated the neural correlates of the "above-average-effect" referring to a self-evaluation bias with a modified version of a social comparative task. The authors reported that activity of the MPFC and the PCC correlated with reduced susceptibility to "above-average"

judgments and activity of the ventral ACC with the differentiation of positive from negative valence, whereas the activity of the orbitofrontal cortex (OFC) and the dorsal ACC correlated negatively with the "above-average-effect".

Finally, Hughes and Beer (2012) examined in their fMRI study "whether neural regions previously implicated in self-serving cognition relate to changes in decision thresholds underlying the extent to which judgments are self-serving" (Hughes & Beer, 2012, p. 890). By providing a modified version of the over-claiming questionnaire and an accountability manipulation the authors could show a correlation between the activation of the OFC, the MPFC and the dorsal ACC and a reduced self-serving bias. Moreover, the less the self-serving bias was pronounced, the more correlated the activity of the medial OFC.

In summary, although several imaging studies employed very similar tasks (especially Blackwood et al., 2003; Seidel et al., 2010), they reported very different results. This could be due to the fact that imaging studies on 'attributions in social situations' hitherto were operated only in relatively small sample sizes (e.g. Blackwood et al. 2003: n = 12). Accordingly, in our study we aimed to increase the statistical power investigating the neural basis of self-attribution in positive and negative social events in a high number of participants and to validate the results with the original Internal, Personal and Situational Attributions Questionnaire, Revised German Version (IPSAQ-R).

To overcome some problems of single studies with small sample sizes, Sperduti et al. (2011) conducted a quantitative meta-analysis across 15 PET and fMRI social cognition studies on the neural correlates of internal- and external-agency attribution in order to cluster (in-)consistent findings. The authors detected – among others – two brain regions consistently implicated: the precuneus and the insula. The precuneus was involved in social processes such as perspective-taking (Ruby & Decety, 2001, 2003), observation of social interaction (Iacoboni et al., 2004), self-referential processes (Iacoboni et al., 2004; Kircher et al., 2000; Spreng, Mar, & Kim, 2009; van der Meer, Costafreda, Aleman, & David, 2010) and causal attribution of social events (Seidel et al., 2010). In addition, Sajonz et al. (2010) discussed an anterior-posterior differentiation of the precuneus with the anterior

portion more involved to self-referential processes and the posterior portion more linked to episodic memory processes. Furthermore, the precuneus along with the medial prefrontal cortex has been discussed as being part either of self-referential processes (Gusnard, Akbudak, Shulman, & Raichle, 2001; Kircher et al., 2002; 2000; Ruby & Decety, 2003; for a review see: Schilbach, Bzdok et al., 2012), of external attribution (Seidel et al., 2010; Sperduti et al., 2011) or of both processes (Ruby & Decety, 2001). Insula activation has been linked to self and current state related phenomena of physiological and emotional awareness and consciousness (Craig, 2009, 2010; Lamm & Singer, 2010; Singer, Critchley, & Preuschoff, 2009) as well as to self-agency attribution (e.g. Farrer & Frith, 2002; Leube et al., 2003; Sperduti et al., 2011).

In summary, a wide variety of brain regions have been linked to attributional biases, mostly including the precuneus and the insula, but with partly inconsistent findings across studies. In our own work, we tested a large sample of healthy participants with fMRI in order to investigate the neural correlates of cognitive processes involved in internal and self-serving attributions across different positively or negatively valenced social situations. We used the IPSAQ scale as a basis for our fMRI task but changed context and semantics of the statements in order to create novel social events with higher ecological validity, i.e. which were closer related to real-life (Schilbach, Timmermans et al., 2012). Further, we compared our behavioral results of the fMRI task with the results from the German version of the original 'paper and pencil' IPSAQ-R (Moritz et al., 2010) in the same subjects to test the reliability and validity of our paradigm. With regard to self-attribution we expected to find activation in a fronto-temporo-parietal network (Blackwood et al., 2003; Seidel et al., 2010), as components of this network are discussed in the context of self-processing (D'Argembeau et al., 2005; Farrer et al., 2003; Johnson et al., 2002; Vogeley et al., 2001). Furthermore, since we included a very large sample size and therefore attained sufficient statistical power, we hypothesized to find a precise distinction among the different sub-regions of the posterior medial parietal cortex (precuneus) involved in differential self-attributional processes (for a review see: Cavanna & Trimble, 2006).

2. Materials and Methods

2.1. Subjects

Eighty-nine healthy subjects from the POSITIVE study, a randomized-controlled multicenter clinical trial (Klingberg et al., 2010), were recruited at six German Universities (measurements took place at five study sites). The inclusion criteria were: (1) age 18–59 years and (2) absence of neurorological or other medical condition, which could affect the results, (3) no mental disorder according to DSM-IV or ICD-10 in the past or in the present assessed with the SCID-I (Structured Clinical Interview for the DSM-IV, German version: Wittchen, Wunderlich, Gruschwitz, & Zaudig, 1997), (4) right handedness (as tested with the Edinburgh Handedness Inventory, Oldfield, 1971), (5) native German speakers with (6) normal or corrected-to-normal vision and (7) no criteria for MRI exclusion (such as metal implants, pregnancy, etc.).

Eighteen participants had to be excluded from the analysis: fMRI data from 8 participants did not meet the quality criteria (in 7 subjects images did not cover the whole brain, 1 revealed scanner-related artifacts; see Stöcker et al. 2005), 8 further participants were excluded due to technical problems (4 incomplete data sets, 2 with intolerable TR deviation of more than 0.1 sec, 1 wrong response-button configuration, 1 missed trigger pulse), two participants were excluded for not following the instructions properly. Accordingly, seventy-one subjects (34 females, 37 males) were finally included in the analyses reported here.

The 71 subjects had a mean age of 34.39 years (SD = 9.06) and a mean estimated verbal intelligence quotient of 115.12 (SD = 17.36) according to the German MWT-B multiple choice vocabulary test (Lehrl, 2005). After a complete description of the procedure, subjects provided written informed consent to participate in the study. The study has received approval from the local ethics committees at all sites and was carried out in accordance with the latest version of the Declaration of Helsinki. After participants provided consent, the cognitive tests and the fMRI experiment were carried out. Because of a further application in a pre-/post-therapy study a neuropsychological battery consisting

of tests measuring verbal intelligence, attention, executive functions, and memory, the IPSAQ-R (Moritz et al., 2010), and the Beads in a Jar Task (Garety, Hemsley, & Wessely, 1991) in an adapted computer version (Moritz & Lincoln, 2008) were administered. Finally participants were paid for their participation.

2.2. Task and Stimuli

2.2.1. FMRI Attributional Bias task

For the fMRI attributional bias task we used statements consisting of one sentence, related to those of the IPSAQ. However, the number of sentences was increased to eighty (forty with positive and forty with negative connotation). We further modified their content: Instead of referring to "a friend" or "a neighbor" as in the original IPSAQ we expanded the other person involved to different identities that were implicated in different social situations. The final forty positive (e.g.: "Your boss appreciates your work in the team") and forty negative social situations (e.g.: "The waitress ignores you in the bar") consisted of six to eight word sentences, which all had the same syntactic structure: subject (singular), predicate (present tense), 1st object (person him-/herself or in relation to person), 2nd object or prepositional phrase.

Due to its further application in a pre-/post-therapy study reported elsewhere, two version of the paradigm were created with two different sets of statements. In a pre-test, both versions were presented to 13 healthy subjects respectively, who were asked to evaluate the criteria (1) positivity/negativity, (2) plausibility, (3) emotionality, and (4) conceivability on a six-point scale. Positive and negative statements did not differ (Wilcoxon-test for paired samples) regarding plausibility (positive sentences: x_{med} = 3.98, negative sentences: x_{med} = 3.84, Z = -1.15, p = .249), emotionality (positive sentences: x_{med} = 3.53, negative sentences: x_{med} 3.83, Z = -.73, p = .463), nor conceivability (positive sentences: x_{med} = 3.83, negative sentences: x_{med} = 3.85, Z = -.70, p = .484). However, as intended, positive and negative statements differed clearly concerning positivity (x_{med} = 4.71 and x_{med} = 1.13 respectively, Z = -3.18, p = .001) and negativity (x_{med} = 1.15 and x_{med} = 4.43

respectively, Z = -3.18, p = .001). Positive and negative sentence were presented in pseudo-randomized order. The two paradigm versions were randomly distributed across subjects.

During the fMRI experiment the sentences were presented visually in white letters on a black screen in a mini-block design for 5 sec each. Every statement was followed by a jittered inter-stimulus interval (3.25 - 10.75 sec) with a white fixation cross on a black screen. Subjects were asked to read the sentences, to imagine the situation happening to them vividly and to decide about the main cause of the situation by answering the question "Who has caused the situation?". Participants had to indicate their attributional decision (internal or external, i.e. whether the situations had been caused by themselves or by the other person involved) by button press with the right index and middle finger respectively. The correct use of the button box was checked before the experiment started. For a schematic representation of the experimental set-up see Fig. 1.

Figure 1 about here

2.2.2. Behavioural task outside the scanner: Internal, Personal and Situational Attributions Questionnaire, Revised Version

The IPSAQ-R validated in German (Moritz et al., 2010) is a translated version of the original Internal, Personal and Situational Attributions Questionnaire (IPSAQ: Kinderman & Bentall, 1996) and consists of 16 items describing eight positive and eight negative situations. For each item, participants were asked to put themselves in the position of someone experiencing a particular situation, to infer the most probable causal explanation for the situation and to write down this explanation. Then they were asked to estimate (in percent) whether their causal explanation was due to internal, personal or situational factors. Three positive interdependent and three negative interdependent subscales were calculated by adding up the percent ratings of internal, personal and situational attributions for positive and negative events. Additionally, an externalizing bias (EB) was computed by subtracting

the internal negative score from the internal positive score. Furthermore, a personalizing bias (PB) was calculated by dividing the personal negative score by the sum of the personal negative score and the situational negative score. Moreover, a monocausality score counted the number of items rated in a monocausal way (i.e. an attributional score was rated with a minimum score of 90%). The IPSAQ-R was administered to the subjects within two weeks prior to the fMRI experiment. As described above, the statements of the IPSAQ-R and the fMRI attributional bias task differed in their number and content (see 2.2.1.).

2.3. FMRI Data

2.3.1. FMRI data acquisition

FMRI measurements took place at five study sites (Bonn, Düsseldorf, Frankfurt am Main, Jülich, Tübingen), all using 3-T Tim Trio MR scanners (Siemens Medical Systems). Functional images were collected using echo planar imaging (EPI) sensitive to BOLD contrast (T2*, 64 × 64 matrix, FoV 200 × 200 mm, voxel size = 3.1 x 3.1 x 3 mm, 36 slices, gap = 10%, 3 mm thickness, TR = 2.25 sec, TE = 30 msec, flip angle = 90°). Slices were measured in ascending order, were positioned transaxially parallel to the anterior-posterior commissural line (AC-PC) and covered the whole brain. 360 functional images were collected. The initial three images were excluded from further analysis in order to remove the influence of T1 stabilization effects.

2.3.2. FMRI data quality control

The fMRI multicenter study was carefully planned and monitored. A detailed study protocol was developed to obtain homogeneous data. The sequences, the paradigm and the scanner comparability were evaluated before the start. Therefore, reliability measurements were performed with 13 healthy subjects being scanned by means of three identical paradigms (simple visual and motor tasks different from the ones reported here) at all fMRI centers involved. Furthermore, MRI sequences and sequence comparability were evaluated across the entire data-acquisition phase by means of MRI phantom measurements applying the identical functional sequence on each scanning

day. The Percent Signal Fluctuation index (PSF_4) was calculated for the phantom data to constantly evaluate and control for center/scanner specific signal fluctuation/noise. Data-acquisition was further monitored and supervised by dint of monthly telephone conferences and several site visits. Finally, we used a fully automated quality assurance routine for fMRI (Stöcker et al., 2005) and discarded poor fMRI data (see 2.1.).

2.3.3. FMRI data analysis

Pre-processing, first level and second level analyses of the functional data were performed using SPM5 (Statistical Parametric Mapping, www.fil.ion.uc.ac.uk/spm). All functional images were slice time corrected, realigned and resliced to the first image to correct for interscan movement, normalized to a standard MNI (Montreal Neurological Institute) template of SPM (resulting voxel size: 2 × 2 × 2 mm), smoothed (8 mm full-width half-maximum isotropic Gaussian filter) and high-pass filtered (cut off period: 128s).

Statistical analysis was performed in a two-level procedure. At the first level, the BOLD responses for the presentation of positive and negative sentences were modeled in mini-blocks (duration = 5 sec) convolved with the canonical hemodynamic response function. Movement parameters and button presses were included in the model as regressors of no interest. The effects for positive and negative sentences were added as contrasts and estimated using the general linear model (GLM) approach. Because of the variability in the design efficiency caused by imbalanced responses, on the first level, we modeled solely positive and negative sentences with two regressors and abandoned the option to estimate additional contrasts for internal and external attribution, since – consistent with the hypothesis of a self-serving bias – several participants had not enough button presses for each condition and thereby not enough events for the statistical analysis (e.g., 36 participants had less than 10 self button presses in negative sentences). Thus, in contrast to Blackwood et al. (2003), there was no need to exclude any participant due to missing trials per condition by incorporating the attributional decision as covariate of interest at the second level (see following description).

The single-subject β-contrasts relating to positive and negative sentences were used for further analyses. On the second level, a paired t-test was calculated for the whole sample of the 71 included participants to investigate the neural correlates of internal and external attribution in positive or negative situations. Statistical parametric maps for the contrasts 'positive sentences > negative sentences' and 'negative sentences > positive sentences' were computed.

Additionally, internal and external attributions were modeled as a covariate of interest containing only the internal/external ratio (percentage of self button presses; higher values indicated more self-attribution) and not the single number of internal and external attributions. This covariate interacted with the experimental factor 'emotional valence' and was therefore split into two parts. Thus, we could estimate different statistical parametric maps by weighting the splitted covariate and had enough degrees of freedom to calculate the following contrasts (T66). With this setup, we addressed three psychological domains ('emotion', 'self-attribution', 'biased self-attribution'), which underlie attributional evaluation processes: (1) *Emotion*: 'positive situations > negative situations', 'negative situations > positive situations'. These contrasts refer to the emotional evaluation of the situations. (2) *Self-attribution*: 'Internal Attribution' (i.e. more self- than other-attributions in both types of situations). This contrast refers to self-attribution processes regardless of the emotional content of the situations. (3) *Biased self-attribution*: 'Internal Attribution Positive > Internal Attribution Negative' (i.e. more self-attributions in positive situations > more self-attributions in negative situations), 'Internal Attribution Negative > Internal Attribution Positive' (i.e. more self-attributions in negative situations > more self-attributions in positive situations). These contrasts refer to the phenomenon of biased self-attribution processes depending on the emotional content of the situations (Moritz et al., 2010).

In addition, we estimated further statistical parametric maps for exploratory analyses: 'External Attribution' (i.e. more other- than self-attributions in both types of situations), 'Internal Attribution Positive' (i.e. more self-attributions than other-attributions in positive situations), 'Internal Attribution Negative' (i.e. more self-attributions than other-attributions in negative situations),

'External Attribution Positive' (i.e. more other-attributions than self-attributions in positive situations), and 'External Attribution Negative' (i.e. more other-attributions than self-attributions in negative situations).

Covariates of no interest were 'button press' modeled by the mean reaction time of each participant, 'misses' containing the individual amount of omitted button presses, and 'recruiting center' consisting of the six sites (coded as five dummy regressors), where subjects were recruited.

Significant activations are reported for a statistical threshold of $p \leq .001$ uncorrected with an extend cluster threshold of $k \geq 20$ voxels. Brain activation was plotted on the anatomical SPM template. Anatomical localization of significant activation in local maxima of the MNI coordinates were identified by using the SPM Anatomy Toolbox (Eickhoff et al., 2005: www.fz-juelich.de/ime/spm_anatomy_toolbox).

2.4. Behavioral and neuropsychological data analysis

Statistical analyses were performed using SPSS 20. With regard to the fMRI attributional bias task, the ratios of internal attributions for positive and negative events were computed controlled for missing data. The number of internal attributions for either positive or negative events was divided by the number of events participants responded to.

With regard to the IPSAQ-R, six participants had to be excluded from the analyses answering less than 75% of the questions (n = 4) or not following the instructions properly (n = 2). The percentage ratings were transformed so that their sum equaled 100% (Moritz et al., 2010). The ratios of internal, personal or situational attributions for positive and negative events were divided by the number of events participants responded to.

In order to test for convergent validity, bivariate relations between the behavioral responses during the fMRI attributional bias task and the IPSAQ-R were computed with Spearman correlation coefficients and corrected for multiple comparisons using a bonferroni correction.

3. Results

3.1. Behavioral data

3.1.1. fMRI attributional bias task

Tab. 1 depicts means and standard deviations of the behavioral responses during the fMRI paradigm. As expected, on a descriptive level, participants showed more internal attributions (attributions to oneself) for positive events in comparison to negative events and a self-serving bias (number of internal attributions for positive events minus number of internal attributions for negative events). 37 participants showed a self-serving bias, only nine participants showed a non-self-serving bias, 25 participants showed none of the two biases. The reaction times did not significantly differ in each condition. The mean reaction times were for internal attribution in positive sentences 3.18 (SD = .84), external attribution in positive sentences 3.18 (SD = .76), internal attribution in negative sentences 3.44 (SD = .78), and external attribution in negative sentences 3.07 (SD = .75)

3.1.2. Internal, Personal and Situational Attributions Questionnaire, Revised Version

Tab. 2 depicts means and standard deviations from the behavioral IPSAQ-R, assessed outside the scanner. On a descriptive level, participants showed mostly internal attributions for positive events, whereas negative events were attributed primarily to personal causes (other person involved). Further, an externalizing bias and a personalizing bias were present.

3.1.3. Validation of the IPSAQ-R and the fMRI attributional bias task

For a comparison of percentage ratios of the fMRI attributional bias task and the IPSAQ-R see Fig. 2. The convergent validity of the fMRI task was investigated, using Spearman correlation analyses. The following positive correlations between the fMRI task and the IPSAQ-R were found: numbers of internal attributions for positive sentences (r = .35, p = .004), numbers of personal attributions for positive sentences (r = .39, p ≤ .001), numbers of personal attributions for negative sentences (r = .30, p = .016), and self-serving bias of both tasks (r = .28, p = .023) were associated with each other, whereas the internal attributions for negative events (r = .09, p = .456) were uncorrelated.

Table 1, 2 and Figure 2 about here

3.2. FMRI data

To cluster our findings with regard to the neural correlates of cognitive processes involved in internal and self-serving attributions across the positively and negatively valenced social situations, we divided our results into three types of whole-brain contrasts by addressing the three involved psychological domains ('emotion', 'self-attribution', 'biased self-attribution'). Further, we report the results of our exploratory analysis.

Emotion

'Positive Sentences > Negative Sentences' revealed activations of the angular gyrus bilaterally (BA 7/39), the right posterior cingulate cortex (BA 23), the right superior frontal gyrus (BA 8), the middle frontal gyrus bilaterally (BA 6/8/45), the left superior frontal gyrus BA (6/8) and the right inferior temporal gyrus (BA20). 'Negative Sentences > Positive Sentences' resulted in activation of the left middle temporal gyrus bilaterally (BA 20/22), the left lingual gyrus (BA 17/18), the calcarine gyrus bilaterally (BA 17/18), the left cuneus (BA 17) and the left posterior cingulate cortex (BA 4), the supramarginal gyrus bilaterally (BA 42/48), the right superior temporal gyrus (BA 21), the right angular gyrus (BA 48) and the left middle occipital gyrus (BA 39) (Tab. 3).

Self-attribution

'Internal Attribution' revealed activation of the right precuneus (BA 7) (Tab. 3).

Biased self-Attribution

'Internal Attribution Positive > Internal Attribution Negative' revealed activation of the right precuneus (BA 7), whereas 'Internal Attribution Negative > Internal Attribution Positive' resulted in activation of the insular lobe bilaterally (BA 45/47) (see Fig. 3) and the left inferior frontal gyrus [pars

triangularis (BA 44/45) and pars orbitalis (BA 47)] as well as the middle frontal gyrus bilaterally (BA 44/46) (Tab. 3).

For a schematic depiction of the above described activations of the posterior cingulate cortex and the precuneus in the three conditions ('emotion', 'self-attribution', and 'biased self-attribution') see Fig. 4.

Exploratory Analysis

'Internal Attribution Positive' revealed activation of the right precuneus (BA 7), whereas 'Internal Attribution Negative' resulted in activation of the left postcentral gyrus (BA 4) and the left supplementary motor area (BA 6/32). 'External Attribution' showed no significant result. 'External Attribution Positive' revealed activation of the left middle frontal gyrus (BA 46) and the left inferior frontal gyrus (BA 45), whereas 'External Attribution Negative' showed no significant result (Tab 3).

Table 3, Figure 3 and 4 and the
Legend of Figure 4 about here

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4. Discussion

In this study, we investigated a large sample of healthy participants with fMRI to explore the neural correlates of cognitive processes implicated in self-attribution of positively and negatively valenced situations. We have validated our fMRI task by means of the original 'paper and pencil' version of the IPSAQ-R (Moritz et al., 2010).

Against most of previous findings in neuroscientific research about self-serving processes (e.g., Blackwood et al., 2003; Hughes & Beer, 2012; Seidel et al., 2010) we mainly found correlations between self-attributional processes in positive and negative sentences and the precuneus, the PCC, and the insular cortex. However, our results are coherent with several studies from cognitive, social, and emotional neurosciences and with classical findings in attributional theory. Notably, we used short sentences to generate attributional processes, which is still very artificial (see limitations).

Details will be discussed in the following sections.

4.1. Task validity

On a descriptive level, participants made more often internal (than external) attributions for positive events during the fMRI paradigm as well as in the IPSAQ-R, while more personal attributions were made in response to negative events. Four of five scores of the fMRI paradigm were significantly associated with comparable results of the IPSAQ-R including a correlation between the self-serving bias scores of both attributional tasks. Internal attributions for negative events in the fMRI paradigm and the questionnaire were unrelated. This might be due to the possibility to choose from three different attributional possibilities in the IPSAQ-R, but only from two in our task, which could have led to a less pronounced attribution of negative events towards internal causes in the IPSAQ-R. As reflected in the significant correlation between both self-serving bias scores, the general tendency of subjects to attribute positive events more often to internal causes in comparison to negative events was similar. Thus, our results demonstrate convergent validity of the fMRI task.

4.2. Precuneus and posterior cingulate cortex

Research in social cognitive neuroscience demonstrated the particular functions of the precuneus and the posterior cingulate cortex (PCC) in social inferential processing (Kuzmanovic et al., 2012), such as mentalizing, intention inference, impression formation and controlled processing (Lieberman, 2010), the interaction between episodic memory and the processing of emotionally salient words (Maddock, 1999; Maddock, Garrett, & Buonocore, 2003) and evaluative judgments (Maddock et al., 2003; Posner et al., 2009). Furthermore, Kuzmanovic et al. (2012) reported increased neural activation of precuneus and PCC when subjective evaluation was based on short text vignettes.

In line with the literature, our results revealed that activation in the precuneus and the PCC was associated with attributional evaluation processes of positive and negative sentences describing social relevant situations in everyday life. Moreover, our data suggest that sub-regions of the precuneus and the PCC are part of different elements of these processes. The whole-brain contrast 'positive sentences > negative sentences' revealed activations of the right PCC, whereas the reverse contrast showed activations of the left PCC. More self-attribution in both types of sentences was

related to activation of the posterior portion of the precuneus. More self-attribution of positive as compared to negative situations (self-serving bias) revealed activation of the right anterior portion of the precuneus. Thus, activation of the PCC could be related to emotional evaluation of the presented situations, whereas activation of the posterior portion of the precuneus could be part of self-ascription processes in the context of the attributional evaluation of the sentences. Further, activation of the anterior portion of the precuneus might reflect functional correlates of self-serving processes during the evaluation of positively valenced situations.

Previous studies discussed different functions of the precuneus (for a review see: Cavanna & Trimble, 2006). One approach assumed a participation of the precuneus in episodic memory retrieval, which for instance was shown by Tulving et al. (1994) and Lundstrom et al. (2003). Another idea is the participation of the precuneus in self-related processes (e.g. Lou et al., 1999; Kircher et al., 2002, 2000; Kjaer et al., 2002).

Our interpretation of a differentiation between anterior and posterior components of the precuneus, refers to the review of Cavanna and Trimble (2006) and is in line with cytoarchitectonic maps (Economo & Koskinas, 1925; Scheperjans et al., 2008) and previous findings from Sajonz et al. (2010). By combining tasks for self-referential processing and episodic memory, Sajonz and colleagues found among common networks three functional differentiations for both processes in the medial and lateral parietal cortex. One finding was the anterior-posterior differentiation in the medial parietal cortex, in particular within the precuneus and the PCC. The authors concluded that there is a "context-dependent neural interplay of anterior and posterior precuneus activation specific for SRP [self-referential processing] and EMR [episodic memory retrieval]". Activations in the antero-superior precuneus and the PCC are rather triggered by self-referential processes, whereas the postero-inferior activation of the precuneus is derived from EMR (Sajonz et al., 2010). Our findings support the thesis of an anterior-posterior division of the precuneus but in a different way. On the one hand, we found evidence for the contribution of the anterior portion of the precuneus and the PCC to self-referential processes distinctly related to the valence of the situations. On the other hand, we found

a contribution to self-referential processes in the posterior portion of the precuneus unrelated to the emotional salience of the sentences.

Concluding, we suggest that the activation of the anterior portion of the precuneus is more related to self-serving tendencies, whereas the posterior portion of the precuneus is rather activated in the attribution of one's self as responsible cause for social situations in general. Thus, the self-serving bias is rather an affective reaction, whereas the general self-attribution in terms of responsibility rather reflects a self-referential process based on a comparison between presented situations and memory of self-experienced events. The idea of a participation of memory processes in attribution was also put forward by Harold Kelley. Charles Antaki (1982) summarized Kelley's concept briefly: "an attribution is arrived at by a search (but not necessarily a conscious one) for the causal candidate which is most closely associated historically with the event being explained". Weiner formulated as a principle for a conscious causal attribution that one has to "search for information, assemble and process this knowledge" (Weiner, 1974, p. 56). These processes are part of the vivid imagination of the presented situations. The portrayed events are compared with one's own experiences in comparable situations. This is especially true because our statements have no background, no broader context and are presented as single sentences in an artificial experimental environment.

4.3. Insula

With increasing self-attribution of the causes of negatively as compared to positively valenced situations, bilateral activation in the insular cortex and the middle frontal gyrus became apparent. By using a task requiring empathy, Lamm et al. (2007) amongst others found bilateral medial and anterior insula activation and left middle frontal gyrus activation when putting one's self into negatively valenced situations. A similar pattern can be seen in our experiment. Internally attributing negatively (as compared to positively) valenced social situations increased activation of the insula and the middle frontal gyrus. Moreover, Farrer and Frith (2002) could show the importance of the insular cortex as a contributor to one's experiencing a sense of agency. In their meta-analysis about the neural correlates of internal- and external-agency attribution, Sperduti et al. (2011) found

bilateral insula activation as most evident for self-agency. The central role of insula in self-agency and self-referential processing is also supported by many studies from lesion and clinical research (e.g., Karnath & Baier, 2010; Voss et al., 2010), by meta-analyses (e.g., van der Meer et al., 2010), and reviews (e.g., Craig, 2009; Singer et al., 2009). Furthermore, Beer and Hughes (2010) suggested that the insula is more associated with judgments of negative valence, which is in line with our finding of bilateral insular activity correlating with self-attributed negative sentences. Although, we could not control for the self-serving bias and therefore, could not proof the self-specificity of the insula activation (see limitations), our findings fit to these results. Thus, we would interpret our findings related to a non-self-serving bias as a correlate of assuming and accepting the responsibility for causes or being aware of oneself in negative social events.

Finally, in context of our findings of the PCC/Precuneus the result of the insular cortex could be discussed with regard to recent findings about the default mode network (DMN). Menon and Uddin (2010) for example suggest the anterior insular as a core region of the salience network (SN). After Menon and Uddin the salience network plays a key role in detecting and processing relevant environmental stimuli by triggering interactions between externally and internally oriented networks (Menon & Uddin, 2010). Furthermore Palaniyappan and Liddle (2012) suggest that "the primary role of the salience network is initiating the recruitment of brain regions relevant for processing currently salient stimuli while decreasing activity in networks engaged in processing previously salient stimuli" (Palaniyappan & Liddle, 2012, p. 23). In this context the authors introduce the concept of proximal salience (PS) as part of the SN (Palaniyappan & Liddle, 2012). Here, PS is understood as a temporary state of neural activity evoked by evaluating external or internal stimuli. Thereafter PS "enables a switching between resting mode to task-processing (executive) mode or vice versa" (Palaniyappan & Liddle, 2012, p. 21). Accordingly, the insula is involved in the process of updating one's prediction model of the world by facilitating the switch between task and non-task (DMN) related brain areas (Palaniyappan & Liddle, 2012). In this sense our finding of insula activity suggests that it could be

more important to switch to DMN processing in situations where internal negative attributions are assigned.

However, we did not design the study to analyze the concept of "proximal salience". Furthermore, the interplay between the SN and the DMN was not explicitly subject of our analyses. We found higher activity in the insula for negative valenced situations compared to positive ones but we did not control for its influence on subsequent DMN activity (as this could be confounded with the bias for negative stimuli). But our findings along with future studies might extend the notion of the salience network and its interplay with the DMN.

5. Limitations

Most of our limitations are based on general problems in attribution research. As Frey (1978) and Weary et al. (1982) pointed out, in public, people have a higher tendency to attribute negative outcomes to internal causes than in privacy. In line with this argument, Hewstone (1989) draws attention to the problems of public-private manipulations in the context of self-esteem and public esteem motives. Furthermore, Lloyd-Bostock (1983) pointed out that "attribution of causes and responsibility involves immensely complex processes and concepts" but "attribution theory appears limited and narrow in emphasis". Thereafter, attribution of causes in a social context is partly structured by "social (including legal) rules, norms and expectations". Although we tried to provide situations in our task, which were drawn from everyday life experiences and asked our participants to imagine these situations vividly, our experimental conditions were still no "real life" social environment. Moreover, by asking for an attribution and giving only two options for an answer, we experimentally reduced the complex attribution options usually unquestioned. However, these limitations are applicable to most, if not all, emotion-related and social experiments which have been conducted in an fMRI setting or in the laboratory.

A more specific problem of our study is, that because of the variability in the design efficiency caused by imbalanced responses, we could not calculate the interaction '(Internal positive + external

negative) > (External positive + Internal negative)'. Hence, we solely could calculate the self-serving bias without controlling for the non-self-serving-bias and vice versa. That limits the conclusions, which can be drawn from our results.

6. Conclusion

In line with our hypothesis we could show that components of a fronto-temporo-parietal network are related to self-referential processes. In particular, we found that the precuneus and the PCC are related to the attributional evaluation of positive and negative sentences describing social relevant situations in everyday life. Moreover, we could differentiate between different subregions within these brain areas. Activation of the PCC is part of emotional evaluation processes, activation of the posterior portion of the precuneus is involved in attributional evaluation processes and activation of the anterior portion of the precuneus is part of self-serving processes evaluating the situation.

In addition, we found an activation of the bilateral insular cortex with increasing self-attributions of negatively valenced as compared to positive social situations. This may be interpreted as a correlate of the acceptance of personal agency and the awareness of oneself in negative social situations.

Finally we could show the validity of our fMRI paradigm and its comparability to the IPSAQ-R.

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Table 1: Behavioral Data fMRI paradigm

Attribution scores	Mean (SD) positive sentences	Mean (SD) negative sentences
Internal score	20.06 (8.26)	11.67 (8.01)
(ratio in percent)	50.62% (20.64%)	29.46% (20.35%)
External score	19.60 (8.30)	28.06 (8.16)
(ratio in percent)	49.38% (20.75%)	70.54% (20.40%)
Ratio internal/external in percent	50.71% (20.71%)	28.79% (19.87%)

Bias	Mean (SD)	
Self-Serving/Externalizing Bias	8.39 (10.66)	
(ratio in percent)	21.16 % (8.24%)	

Means and standard deviations for the fMRI attributional bias task (n = 71)

Table 2: Results of the Internal, Personal and Situational Attributions Questionnaire, revised version (IPSAQ- R; Moritz et al., 2010)

Attribution scores	*Mean (SD)* *positive sentences*	*Mean (SD)* *negative sentences*
Internal score	468.23 (202.72)	307.83 (114.13)
(ratio in percent)	53.03 % (29.72 %)	29.41 % (14.27 %)
Personal score	219.74 (100.32)	331.91 (132.42)
(ratio in percent)	29.14 % (12.74 %)	42.08 % (16.55 %)
Situational score	117.91 (103.00)	197.73 (255.42)
(ratio in percent)	17.83 % (14.83 %)	28.51 % (31.93 %)
External score	339.03 (107.96)	524.70 (227.71)
(ratio in percent)	46.97 % (13.39 %)	70.59 % (28.27 %)

Bias	*Mean (SD)*
Externalizing Bias	160.40 (199.90)
(ratio in percent)	20.05 % (24.99 %)
Personalizing Bias	.66 (66 %)
(ratio in percent)	.59 (20%)
Monocausality	1.37 (8.6 %)
(sum of ratings above 90%)	2.64 (16.5 %)

Means and standard deviations for the IPSAQ- R (n = 65)

Region	Hemisphere	x	y	z	k_E	Max. SPM (T)
EMOTION						
Positive>Negative Sentences						
Angular gyrus	R	40	-62	54	178	3.99
Posterior cingulate cortex	R	2	-40	32	166	4.61
Superior frontal gyrus	R	20	30	58	72	4.95
Middle frontal gyrus	L	-24	18	62	68	4.60
Superior frontal gyrus	L	-20	30	58	68	3.89
Inferior temporal gyrus	R	58	-14	-28	67	4.61
Middle frontal gyrus	R	46	46	14	28	3.68
Angular gyrus	L	-44	-68	50	23	3.40
Negative>Positive Sentences						
Middle temporal gyrus	L	-52	-14	-12	334	4.62
Lingual gyrus	L	-12	-50	2	212	4.43
Calcarine gyrus	L	-12	-54	6	212	4.40
Cuneus	L	-16	-58	18	212	3.50
Calcarine gyrus	R	14	-50	8	119	4.14
Posterior cingulate cortex	L	-6	-22	44	101	4.25
Supramarginal gyrus	L	-56	-48	26	86	4.33
Superior temporal gyrus	R	56	-22	0	56	3.63
Middle temporal gyrus	R	60	-10	-8	51	3.68
Angular gyrus	R	52	-46	30	53	3.85
Supramarginal gyrus	R	56	-44	30	53	3.83
Middle occipital gyrus	L	-38	-78	30	35	3.74
SELF-ATTRIBUTION						
Internal Attribution						
Precuneus	R	8	-60	50	67	4.26
BIASED SELF-ATTRIBUTION						
Internal Attribution Positive> Internal Attribution Negative						
Precuneus	R	4	-42	46	64	4.71
Internal Attribution Negative> Internal Attribution Positive						
Insula lobe	L	-36	18	-2	246	4.46
Inferior frontal gyrus (pars triangularis)	L	-48	20	-2	246	3.36
Insula lobe	R	40	24	0	125	4.64
Inferior frontal gyrus (pars orbitalis)	L	-48	42	-12	82	4.36

Middle frontal gyrus	R	50	28	36	45	4.07
Middle frontal gyrus	L	-32	48	14	37	3.69

EXPLORATIVE ANALYSIS

Internal Attribution Positive

Precuneus	R	8	-60	52	257	4.80

Internal Attribution Negative

Postcentral gyrus	L	-54	-18	50	32	3.73
Supplementary motor area	L	-8	16	46	22	3.68

External Attribution
No significant results

External Attribution Positive

Middle frontal gyrus	L	-36	46	14	35	3.80
Inferior frontal gyrus	L	-36	44	10	35	3.70

External Attribution Negative
No significant results

Coordinates of the peak voxels of each cluster are listed in MNI atlas space. (n = 71)
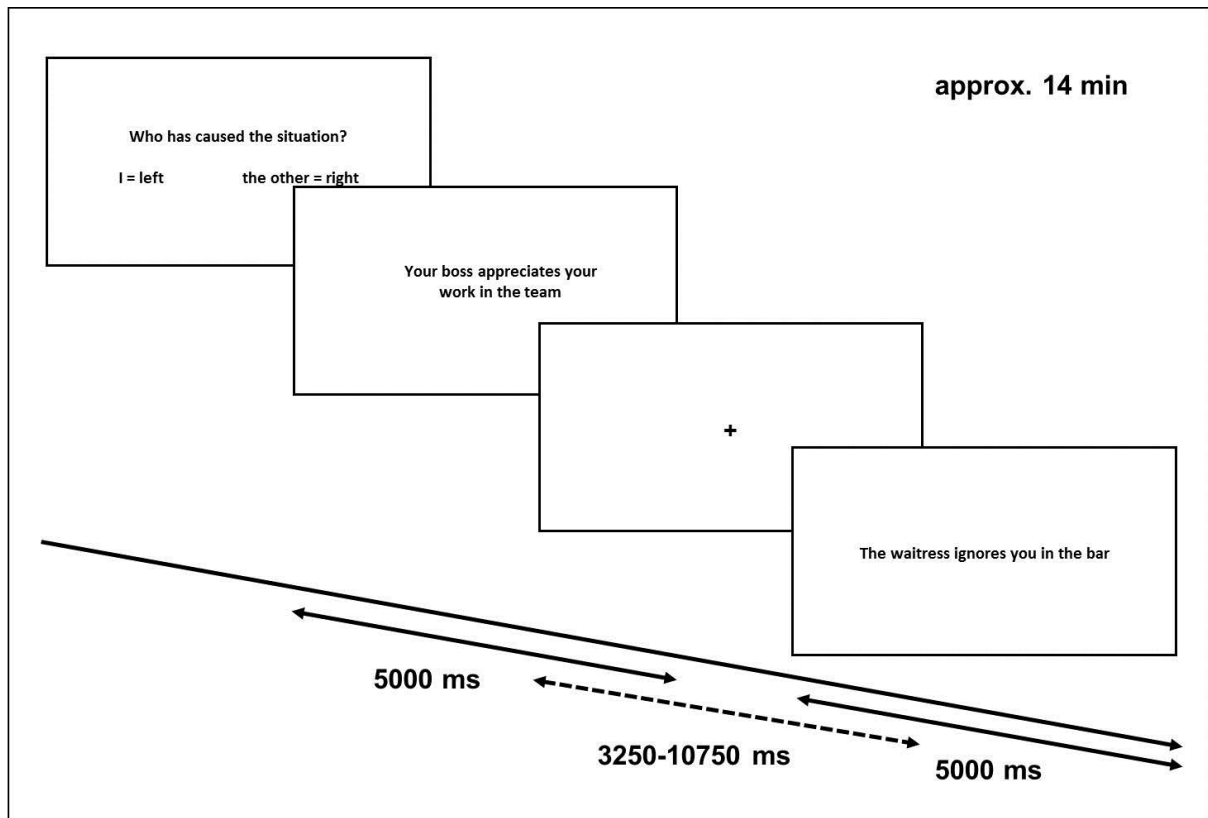
Figure 1: FMRI attributional bias task. 40 positive and 40 negative social situations were presented. Subjects had to decide whether the positive or negative situations had been caused by themselves or by the other person involved.
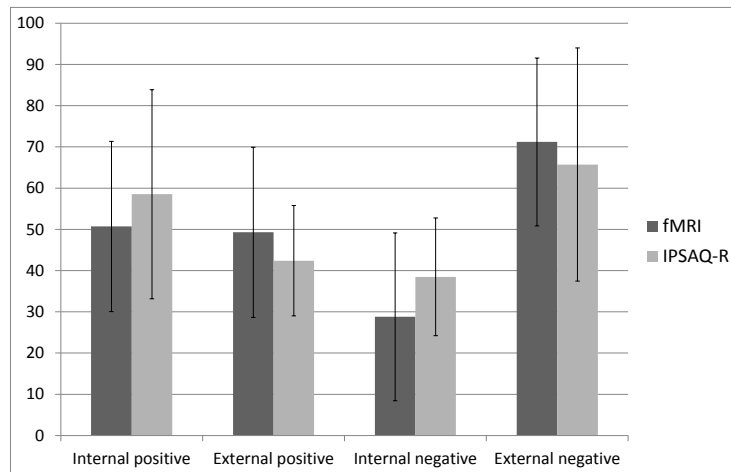
Figure 2: Depiction of percentage ratios (means and standard deviations) from the internal and external attributions in the fMRI attributional bias task (dark grey) and the IPSAQ-R (light grey) (Moritz et al., 2010).
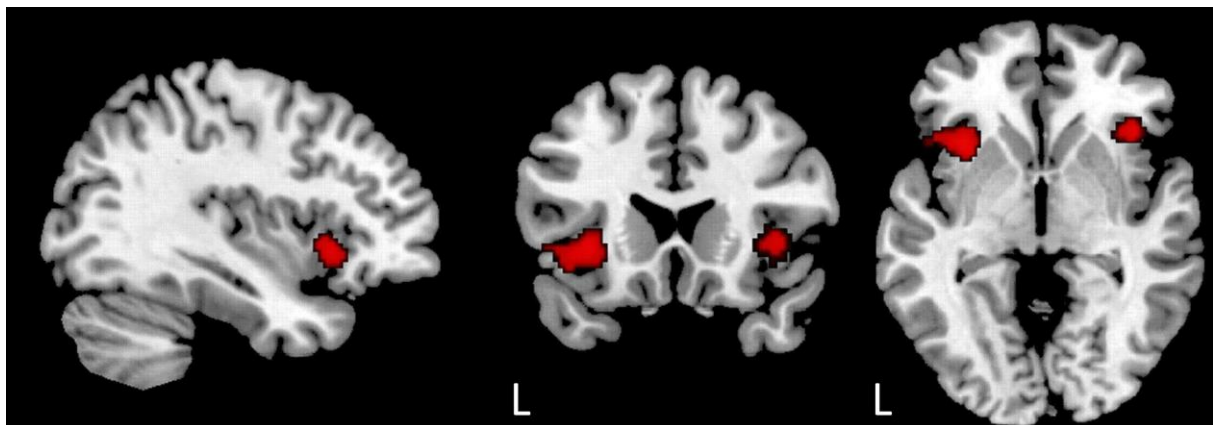

Figure 3: The bilateral anterior insula cortex is activated in the contrast of covariate 'Internal Attribution Negative > Internal Attribution Positive', p=.001 unc.
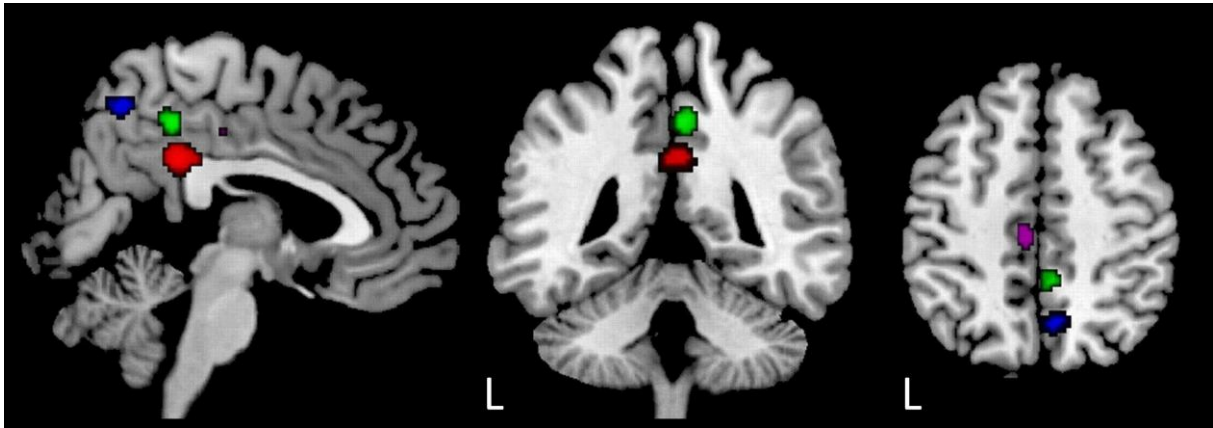
Figure 4: Schematic depiction of the precuneus and posterior cingulate cortex in different contrasts addressing three psychological domains ('emotion', 'self-attribution', 'biased self-attribution'), p= .001 unc.