The dark side of self-focus: brain activity during self-focus in low and high brooders

Maxime Freton,[1,2,3] Cédric Lemogne,[4,5,6] Pauline Delaveau,[1,3] Sophie Guionnet,[1,2,3] Emily Wright,[1,3] Emmanuel Wiernik,[1,3,4,6] Eric Bertasi,[1,7] and Philippe Fossati[1,2,3]

[1]Université Pierre et Marie Curie (UPMC), Faculté de Médecine, Paris, France, [2]Department of Psychiatry, AP-HP, Hôpital Pitié-Salpêtrière, Paris, France, [3]CNRS USR 3246, Paris, France, [4]Université Paris Descartes, Sorbonne Paris Cité, Faculté de Médecine, Paris, France, [5]AP-HP, Hôpitaux Universitaires Paris Ouest, Service Universitaire de Psychiatrie de l'adulte et du Sujet Âgé, Paris, France, [6]Inserm U894, Centre Psychiatrie et Neurosciences, Paris, France, and [7]Centre de NeuroImagerie de Recherche—CENIR, Centre de Recherche de l'Institut du Cerveau et de la Moelle Épinière, Inserm U975, CNRS UMR7225, Groupe Hospitalier Pitié-Salpêtrière, Paris, France

There are two distinct modes of self-focus: analytical self-focus is abstract, general and evaluative whereas experiential self-focus is concrete, specific and non-evaluative. Using functional magnetic resonance imaging (fMRI), we investigated the neural bases of these two modes of self-focus in relation with brooding, the maladaptive form of rumination. Forty-one French-speaking right-handed healthy young adults (10 men, mean age ± s.d.: 21.8 ± 2.3 years) engaged in analytical and experiential self-focus triggered by verbal stimuli during fMRI. Brooding was measured with the 22-item Rumination Response Style scale. Individuals with lower brooding scores showed greater activation of the posterior cingulate cortex/precuneus during analytical than experiential self-focus, whereas individuals with higher brooding scores did not. This is consistent with the hypothesis that brooding is associated with less control over the nature of the self-focus engaged. These findings may help to refine our understanding of how rumination promotes depression through maladaptive self-focus.

INTRODUCTION

Major depression is associated with an increased attention to the self, namely self-focus (Mor and Winquist, 2002). Self-focus may be operationalized in social neuroscience as the process by which individuals engage in self-referential processing (i.e. the appraisal of stimuli as strongly related to one's own person) (Lemogne et al., 2012). Self-referential processing in healthy subjects is associated with activation of the cortical midline structures (CMS) (Fossati et al., 2003; Northoff et al., 2006). Several studies have examined the neural bases of self-referential processing in depressed individuals (Grimm et al., 2009; Lemogne et al., 2009; Johnson et al., 2009; Yoshimura et al., 2010) or vulnerable individuals (Lemogne et al., 2011) and found either an increased or a decreased activation of the CMS. Although these discrepancies may result from methodological differences (Lemogne et al., 2012; Nejad et al., 2013), they may also result from the fact that self-focus is not a unitary process but rather encompasses at least two components, referred to as 'analytical' and 'experiential', respectively. Analytical self-focus is characterized by an abstract evaluation of the self as a continuous object of knowledge, whereas experiential self-focus is characterized by a concrete, awareness of the self as the subject of immediate experience in the moment (Watkins, 2008). Farb et al. (2007) found that anterior and posterior CMS to be more active during analytical than experiential self-focus, whereas left-lateralized regions, including dorsal and ventral lateral prefrontal cortex (PFC) and posterior parietal cortex, were more active during experiential than analytical self-focus. This study aimed to examine neural activations during analytical vs experiential self-focus among healthy subjects, in relation to individual differences in rumination.

According to Nolen-Hoeksema (1991), rumination is a style of response to psychological distress that involves repetitively and passively focusing on symptoms of distress and possible causes and consequences of theses symptoms. An exploratory factorial analysis of the Ruminative Responses Scale (RRS) yielded two factors labelled as reflective pondering (a purposeful turning inward to engage in cognitive problem solving to alleviate one's depressive symptoms) and brooding (a passive comparison of one's current situation with some unachieved standard) (Treynor et al., 2003). In contrast with reflective pondering, brooding is associated with negative affect and impaired cognitive control in healthy subjects, and with negative attentional biases, severity and duration of depressive episodes, and increased risk of relapse in currently and formerly depressed patients (Joormann et al., 2006; Whitmer and Banich, 2007; Nolen-Hoeksema et al., 2008). Several studies have examined the correlations between inter-individual differences in rumination and neural activations during functional magnetic resonance imaging (fMRI) tasks among healthy and depressed individuals (Siegle et al., 2002; Ray et al., 2005; Johnson et al., 2009; Berman et al., 2011a,b; Farb et al., 2011; Hamilton et al., 2011; Vanderhasselt et al., 2011; Zhu et al., 2012; Paul et al., (2013); Nejad et al., 2013). Altogether, these studies suggest that (i) rumination scores are positively correlated with functional connectivity within the so-called 'default mode network' at rest (including the anterior and posterior midline structures); (ii) rumination scores are positively correlated with an increased activation of the lateral PFC during the processing of negative stimuli or externally oriented tasks, possibly underlying greater cognitive efforts to disengage from self-focus; and (iii) these differences are specifically associated with brooding but not reflective pondering. To our knowledge, only one fMRI study examined the neural bases of self-referential processing in relation with rumination among depressed and healthy individuals. Higher rumination scores were associated with greater anterior and posterior medial cortex activation during non-self-referential task, consistent with difficulties to disengage from spontaneous self-focus (Johnson et al., 2009). To our knowledge, however, the neural correlates of rumination have never been examined in relation to analytical vs experiential self-focus among healthy subjects.

To address this question, we conducted a method in two steps: (i) we performed a contrast analysis (analytical *vs* experiential self-focus) to determine regions more specifically activated during one condition compared with the other and (ii) we performed correlation analyses between rumination scores and the activity of regions identified in the first step during analytical *vs* experiential self-focus. Farb *et al.*, (2007) and Johnson *et al.* (2009) found less activity in anterior and posterior CMS during experiential than analytical self-focus in healthy participants. First, we expected this difference of activity to be reduced in participants with high levels of rumination. In other words, we hypothesized that rumination would be associated with unwanted analytical self-focus during the experimental induction of experiential self-focus, thus leading to a negative correlation between rumination scores and activation of the anterior and posterior CMS, in analytical *vs* experiential self-focus. Such an outcome would be consistent with the idea that individuals with high levels of rumination are less able to control the nature of the type of self-focus they engage. Second, we thus hypothesized that rumination would be associated with more cognitive control during experiential self-focus in order to inhibit unwanted and automatic analytical self-focus, thus leading to a positive correlation between rumination scores and activation of the cognitive control network in experiential *vs* analytical self-focus. Third, we predicted that these correlations would be specific of the brooding component of rumination, thus highlighting the neural correlates of the dark side of self-focus.

MATERIALS AND METHODS
Participants

All participants were French-speaking right-handed healthy young adults and gave written informed consent after complete description of the study. The Ethics Committee for Biomedical Research of the Pitié-Salpêtrière Hospital approved the study. The volunteers were screened for past and present DSM-IV diagnoses with the Mini International Neuropsychiatric Interview (Sheehan *et al.*, 1998) and for nicotine dependence with the Fagerström Scale (Heatherton *et al.*, 1991). Exclusion criteria were current or past psychiatric disorders (including substance-related disorders), medical disorders or medication likely to affect cognition, left-handedness and prior meditation or psychotherapy experience. Forty-one right-handed healthy subjects were included in the study (10 men, 31 women, mean age ± s.d.: 21.8 ± 2.3 years). Vision was normal or corrected to near normal using contact lenses.

Procedure

The experiment took place over two sessions separated by an average interval (±s.d.) of 12.8 ± 8.3 days. The first session included in the following order: screening for exclusion criteria, questionnaires administration, training in differentiating analytical and experiential self-focus. At the second session, participants performed the fMRI task.

Questionnaires

Rumination was assessed with the French translation of the 22-item RRS (Nolen-Hoeksema and Morrow, 1993; Guimpel *et al.*, 2012). Participants are asked to indicate how often they engage in each of 22 ruminative thoughts or behaviours when they feel sad, blue or depressed. Separator scores were computed for Brooding (RRSb) and Reflective pondering (RRSr) subscales. Both subscales have been found to have acceptable internal consistency ($\alpha = 0.77$ and 0.72 for RRSb and RRSr, respectively) and test–retest reliability ($r = 0.62$ and 0.60 for RRSb and RRSr, respectively). Depressive symptoms over the preceding two weeks were measured with the Beck Depression Inventory II (BDI-II), which is a reliable and valid questionnaire of 21 items (Bourque and Beaudette, 1982).

Self-focus task

Participants were trained as regards the distinction between experiential and analytical self-focus. The stimuli were 28 short phrases designating sensations, feelings or thoughts selected to trigger self-focused attention (e.g. 'the physical sensations in your body') adapted from Nolen-Hoeksema and Morrow's (1993) rumination task. The instructions were adapted from Watkins and Teasdale (2001) and both conditions (i.e. analytical or experiential self-focus) used the same stimuli. The instructions in the experiential self-focus were: 'As you read the items, use your imagination and concentration to focus your mind on each experience. Spend a few moments visualizing and concentrating on your experience, attempting to find a phrase, image or set of words that best describes the quality of what you sense'. The instructions in the analytical induction were: 'As you read the items, use your imagination and concentration to think about the causes, meanings and consequences of the items. Spend a few moments visualizing and concentrating on each item, attempting to make sense of and understand the issues raised by each item'. The participants worked at their own pace for 10 min in each self-focus condition. The order of the conditions was counterbalanced across participants.

fMRI task design

A list of 36 short phrases (6 for the practice run and 30 for the scanning runs) describing sensations, feelings and thoughts were constructed, adapted from Nolen-Hoeksema and Morrow's (1993) rumination task (please see Supplementary Appendix S1 for the list of stimuli). These items had neutral emotional valence and were constructed to trigger self-referential processing. Each item was used two times: one time in analytical self-focus condition and one time in experiential self-focus condition. The order in which stimuli were used was randomized for each subject. Immediately before the task, the analytical and experiential instructions of self-focus instructions were recalled to the participants. Each participant completed one practice run outside the scanner and four scanning runs. Each run consisted of two blocks of analytical self-focus and two blocks of experiential self-focus, in random order. Before each block, an instruction cue was presented for 8 s: 'Think about...' for the analytical self-focus condition and 'Focus your attention on your experience of...' for the experiential self-focus condition. During each block, participants performed analytical or experiential self-focus during 30 s based on three items presented during 10 s each (the stimulus presented for 2.5 s and a fixation cross presented for 7.5 s). After each block, an instruction to disengage from self-focus was presented for 3 s, followed by a rest fixation cross presented for 7.5 s. Owing to technical problems, fMRI data were lost regarding one run for four participants and two runs for one participant.

fMRI scanning

Stimuli were generated and presented with E-Prime 2.0 and projected on a plexiglas screen mounted at the end of the scanner bore. Five functional runs of 102 contiguous volumes were acquired on a 3T Trio TIM MR-scanner (Siemens Medical Solutions, Erlangen, Germany) with Siemens standard 12-channel head coil. Subjects' head movements were restrained by foam paddings, inside of the head coil. Functional images covering the whole brain were acquired using a T2-weighted gradient echo, echo planar imaging (EPI) sequence, sensitive to blood oxygen level-dependent signal, employing the following parameters: 41 axial slices, repetition time: 2 s, echo time: 25 ms, flip angle: 90°, bandwidth: 2230 Hz, matrix: 64 × 64, field of

view: $192 \times 192 \, mm^2$, isotropic voxel size of $3 \times 3 \times 3 \, mm^3$, GRAPPA acceleration factor: 2. Each run lasted 194 s. The first two volumes of each run were discarded to reach signal equilibrium. High-resolution three-dimensional T1 weighted images (3D fast gradient echo inversion recovery sequence, inversion time: 400 ms, repetition time: 2300 ms, echo time: 4.18 ms, bandwidth: 150 Hz, flip angle: 98°, matrix: 256×256, field of view: $220 \times 220 \, mm^2$, voxel size: $1 \times 1 \times 1 \, mm^3$) were acquired for anatomical localization.

fMRI data analysis

We used SPM5 software (http://www.fil.ion.ucl.ac.uk/spm/software/spm5) for data analysis. EPI volumes were corrected for slice timing, realigned to the first image, co-registered with the high-resolution T1-weighted image, and normalized into a standard stereotactic space. The normalization used the Montreal Neurological Institute (MNI) template and the transformations computed during the segmentation of the high-resolution T1-weighted image. Finally, the normalized EPI volumes were smoothed using an isotropic Gaussian kernel filter of 8 mm full-width at half-maximum. Each trial onset was convolved with the canonical haemodynamic response function (HRF) scaled relative to the self-focus condition block and rest fixation cross durations (30 s and 7.5 s, respectively), to create regressors of interest. A high-pass filter with a default cutoff of 128 s was applied and the motion realignment parameters were included as regressors of non-interest. The analytical vs experiential first-level individual contrast images were obtained for the HRF estimates.

Statistical analysis

First, we aimed to identify the specific neural correlates of the two modes of self-focus. We performed two random effect second-level one-sample t-tests with the analytical vs experiential first-level contrast images. A whole-brain analysis was performed using a combined threshold of uncorrected voxel $P < 0.005$ with 20 contiguous voxels, to produce a reasonable balance between Type I and Type II error rates (Lieberman and Cunningham, 2009).

Second, these results were used as inclusive masks in further analyses to examine how the activation of these regions was modulated by levels of rumination. We conducted multiple regression analyses using analytical vs experiential contrast images as dependent variables and RRSb scores and RRSr scores separately as independent variables. These analyses were threshold at uncorrected voxel $P < 0.005$ with 20 contiguous voxels (Lieberman and Cunningham, 2009). Whenever a significant correlation was found in one region, we conducted post hoc correlation analyses in SPSS (SPSS Inc, Chicago, IL) between rumination scores and mean activation (extracted with MarsBaR toolbox) in the analytical vs experiential contrast.

RESULTS

Psychometric results

RRSb and RRSr scores means ($\pm$s.d.) were, respectively, 9.2 ± 3.3 and 9.2 ± 3.4. As expected, participants had low BDI-II scores (mean $\pm$ s.d.: 2.8 ± 3.3). Depressive symptoms were significantly and positively correlated with RRSb ($r = 0.442$, $P = 0.004$) but not with RRSr ($r = 0.199$, $P = 0.212$).

fMRI results

Table 1 displays regions that were more active during analytical than experiential self-focus, and inversely. As regards analytical vs experiential self-focus, the largest cluster was located in the posterior CMS and encompassed bilateral posterior cingulate cortices, precuneus and cuneus (Brodmann areas: 31, 23 and 18) (Figure 1, left panel).

As regards experiential vs analytical self-focus, the largest clusters were found in lateral cortical structures only: bilateral middle and inferior frontal gyrus, bilateral inferior parietal lobule, bilateral lateral temporal cortex and right fronto-insular cortex (Figure 1, right panel).

Among these regions of interest (ROIs), Table 2 displays those in which the differential activation between the two modes of self-focus was associated with RRSb scores. The multiple regression analysis revealed negative correlation between RRSb scores and neural activity during analytical vs experiential self-focus in the posterior cluster that was more specifically activated during analytical vs experiential self-focus ($r = -0.519$, $P = 0.001$), and specifically in the posterior cingulate cortex/precuneus (Figure 2).

Scatter plots between mean percent signal change of the significant clusters and RRSb scores revealed an outlier with a high RRSb score of 19 (Figure 2). The analysis was repeated after removing this outlier and yielded similar results. No correlation was found between RRSr scores and the activity of any selected brain region during analytical vs experiential self-focus condition. After adjustment for BDI-II scores, this correlation remained significant.

DISCUSSION

The aim of this study was to examine the association between rumination and the neural activations during analytical vs experiential self-focus in healthy subjects. Consistent with our first hypothesis, healthy subjects with lower brooding scores showed greater activation of the posterior CMS during analytical than experiential self-focus, whereas those with higher brooding scores showed less difference. In contrast, our second hypothesis was not supported as we did not find any correlation between rumination scores and activation of the cognitive control network in experiential vs analytical self-focus. Finally, consistent with our third hypothesis, our results were specific to brooding and we did not find any correlation between reflective pondering score and neural activation during analytical vs experiential self-focus.

The results of the preliminary contrast analyses, which examined specific activations associated with analytical and experiential self-focus relative to each other, revealed similar results to Farb et al. (2007) and Johnson et al. (2009). Analytical self-focus specifically engaged a large cluster with the posterior CMS encompassing the posterior cingulate cortices, cuneus and precuneus. These regions are involved in mental imagery, autobiographical memory, self-projection, scene construction and theory of mind (Spreng et al., 2009). These functions are consistent with the nature of analytical self-focus which deals with the extended, narrative self rather than with immediate experience (Gallagher, 2000; Trope and Liberman, 2003). Relative to analytical self-focus, experiential self-focus engaged the bilateral dorsolateral prefrontal and inferior parietal lobules, both being part of the frontoparietal attention and control network (Corbetta et al., 2008; Vincent et al., 2008). These networks are, respectively, involved in attention reorienting and rapid adaptive control, consistent with the nature of experiential self-focus that requires directing and maintaining attention towards immediate experience. Furthermore, activations in the inferior parietal lobule (embodied self), the right mid-insula (interoceptive awareness) and the ventrolateral temporal (semantic system associated with concrete concepts) are also consistent with attention to the current, concrete experience of the self (Martin and Chao, 2001; Craig, 2010; Blanke, 2012).

Overall, the fact that individuals with higher brooding scores showed a reduced difference in posterior cingulate cortex/precuneus activity during analytical vs experiential self-focus suggests that they have more difficulties in differentiating the two conditions (i.e. they were less able to control the nature of the self-focus they engage).

Table 1 Regions that were more active during analytical than experiential self-focus and inversely, in a whole-brain one-sample *t*-test

Regions	Brodmann area	MNI coordinates (*x, y, z*)	*t*	Cluster corrected *P*	Cluster size (voxels)
Analytical > experiential					
Posterior cingulate, precuneus, cuneus and R cerebellum posterior lobe declive	**31, 23, 18**	**2, −58, 24**	**5.90**	**<0.001**	**6322**
		8, −56, 12			
		−10, −76, 14			
		20, −68, −20			
L ventromedial frontal gyrus	11	−10, 54, −10	4.10	0.844	90
L superior frontal gyrus	6	−4, 6, 64	4.88	0.718	106
	9	−14, 38, 40	3.35	1.000	20
	9	−16, 54, 34	3.26	0.997	48
Superior temporal gyrus	38	56, 12, −14	4.01	0.997	48
		−50, 14, −24	3.71	0.995	51
Middle temporal gyrus	21	−56, −8, −10	3.47	1.000	33
		−46, −36, −2	3.41	0.998	45
		46, −30, 0	3.35	0.998	46
Experiential > analytical					
L middle and inferior frontal gyrus	**46, 10**	**−44, 46, 18**	**6.10**	**<0.001**	**673**
R middle and inferior frontal gyrus	**46**	**16, 34, −16**	**4.84**	**0.001**	**547**
R fronto-insular cortex	**44, 6, 13**	**58, 2, 12**	**5.35**	**<0.001**	**634**
		48, 0, 8			
Inferior parietal lobule	**40**	**−58, −40, 46**	**5.33**	**<0.001**	**1452**
		50, −36, 48	**5.54**	**<0.001**	**1271**
R fusiform and middle temporal gyrus	**37, 21**	**50, −52, −18**	**4.35**	**<0.001**	**653**
L fusiform and inferior temporal gyrus	37, 19	−42, −32, −18	4.95	0.002	501
L temporo-occipital junction cortex	19	−28, −70, 26	4.69	0.372	152
L middle occipital gyrus	18	−34, −78, 0	3.74	0.998	46
L superior temporal gyrus	22	−52, −8, 2	3.42	1.000	24
L superior parietal lobule	7	−16, −62, 60	3.76	0.271	171
Medial frontal gyrus supplementary motor area	6	6, −8, 62	4.43	0.249	176
R middle frontal gyrus	8	42, 32, 42	3.55	0.999	41
	10	42, 44, 24	3.30	0.958	69
R inferior frontal gyrus	10	34, 62, 4	3.38	1.000	24
L insula	13	−32, −18, 8	3.65	1.000	34
		−36, −6, 12	3.30	1.000	23
R parahippocampal gyrus	28	30, −14, −20	3.24	0.990	56

L, left; R, right. MNI coordinates of maximum *t*-scores are shown for each cluster. *P* < 0.005 uncorrected voxel threshold, and 20 voxels extend threshold. Clusters corrected *P* ≤ 0.001 in bold.
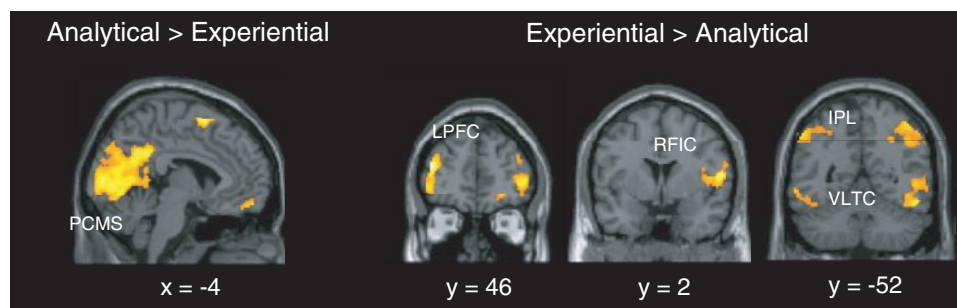

Fig. 1 Regions specifically activated during one self-focus condition compared with the other in a whole-brain one-sample *t*-test. (20 contiguous voxels, *P* < 0.005) The largest areas activated in analytical *vs* experiential contrast are displayed on the left panel, and those activated in experiential *vs* analytical contrast are displayed on the right panel. PCMS, posterior cortical midline structures; LPFC, lateral prefrontal cortex; RFIC, right fronto-insular cortex; IPL, inferior parietal lobule; VLTC, ventrolateral temporal cortex.

Posterior CMS are known to show higher activity during stimulus-independent and task-unrelated processing compared with externally oriented tasks (Mason *et al.*, 2007; Buckner *et al.*, 2008). Recent studies found this region to display greater activity during externally oriented tasks and greater functional connectivity at rest in individuals prone to ruminate. For instance, Grimm *et al.* (2009) found higher activation of the precuneus during an externally oriented task in depressed individuals. Berman *et al.* (2011b) found greater functional connectivity between anterior and posterior CMS at rest in depressed individuals, and especially in those with higher brooding, but not reflection pondering scores. Closer to the present results, Johnson *et al.* (2009) found higher

activation of a very similar region within the posterior CMS (Talairach coordinates of the peak: −4, −55, 32) during a concrete, internally oriented (but non-self-referential) task in depressed *vs* healthy individuals, especially in those with higher rumination scores. Interestingly, this structure was less modulated between analytical and experiential self-focus in the depressed subjects of Johnson *et al.* (2009) compared with healthy individuals, mirroring the present results obtained comparing high *vs* low brooders healthy subjects (Table 2, Figure 2). Therefore, negative correlations between brooding score and the posterior CMS during analytical *vs* experiential self-focus could be interpreted as a difficulty for brooders to disengage from spontaneous and

unwanted thought during experiential *vs* analytical self-referential processing.

A limitation of the present design is that the neural results could be attributed to processes in general that have abstract *vs* concrete properties as opposed to these properties in the context, specifically, of self-focus. Contrasting with our results, meta-analyses showed a greater activation of the posterior cingulate cortex/precuneus during concrete *vs* abstract semantic processing of words, possibly explained by the role of these regions in mental imagery processes (Binder *et al.*, 2009; Wang *et al.*, 2010). However, recent studies showed a greater activation of these regions during abstract *vs* concrete mindset processing (Spunt *et al.*, 2010; Gilead *et al.*, 2013). To address this issue, further studies would need to add another level to the experimental paradigm involving abstract *vs* concrete processing in a non-self-focused context.

Some others limitations should be acknowledged. We did not use online or post-scanning subjective measures of automatic and unwanted thought during fMRI. We chose this method because we did not want to introduce another cognitively demanding task that would have interfered with automatic self-focus. Second, we only used neutral stimuli so that we could not examine the potential effects of stimuli emotional valence. Third, we excluded subjects with current or past depressive disorders. We chose this method to examine the neural correlates of rumination independently from depressive mood. However, rumination and analytical self-focus have been found to have detrimental effects in dysphoric or depressed subjects, specifically (Nolen-Hoeksema *et al.*, 2008; Watkins, 2008). Further studies may explore the neural correlates of analytical *vs* experiential self-focus in relation to both rumination levels and current state of mood.

Overall, these limitations do not invalidate our main findings, showing that the maladaptive form of rumination, captured by a high brooding score, is associated with a reduced difference of the posterior cingulate cortex/precuneus activity between analytical and experiential self-focus. These findings may help to refine our understanding of how rumination paves the way to depression at a brain level.

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

Conflict of Interest

None declared.

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Table 2 Negative correlation between RRSb scores and ROIs' activation during analytical *vs* experiential self-focus in multiple regression analyses

Regions	MNI coordinates (*x, y, z*)	*t*	Cluster size (voxels)
Posterior cingulate cortex/precuneus	10, −46, 34	4.04	71
	−12, −40, 36	3.65	
	−2, −42, 36	3.34	

MNI coordinates of maximum *t*-scores are shown for each cluster. Voxel uncorrected threshold: $P < 0.005$ and extend threshold: 20 voxels.
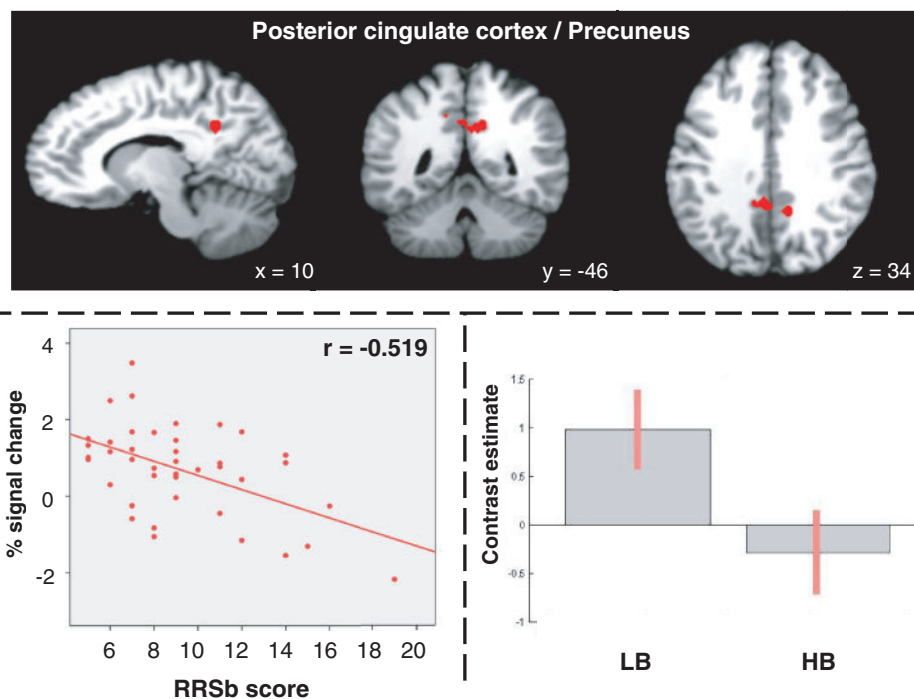

Fig. 2 Images (top panel) and scatter plot (bottom left panel) show the posterior cingulate/precuneus region whose activation during analytical *vs* experiential self-focus is negatively correlated with the RRSb score (20 contiguous voxels, $P < 0.005$). (bottom right panel) Bar graphs show the magnitude of activations associated with the analytical *vs* experiential contrast in the low brooding (LB) and high brooding (HB) groups, based on a RRSb score median-split.

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