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Sex differences in brain activation patterns during processing of positively and negatively valenced emotional words

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ABSTRACT

Background. Previous studies have suggested that men and women process emotional stimuli differently. In this study, we used event-related functional magnetic resonance imaging (fMRI) to investigate gender differences in regional cerebral activity during the perception of positive or negative emotions.

Method. The experiment comprised two emotional conditions (positively/negatively valenced words) during which fMRI data were acquired.

Results. Thirty-eight healthy volunteers (19 males, 19 females) were investigated. A direct comparison of brain activation between men and women revealed differential activation in the right putamen, the right superior temporal gyrus, and the left supramarginal gyrus during processing of positively valenced words *versus* non-words for women *versus* men. By contrast, during processing of negatively valenced words *versus* non-words, relatively greater activation was seen in the left perirhinal cortex and hippocampus for women *versus* men, and in the right supramarginal gyrus for men *versus* women.

Conclusions. Our findings suggest gender-related neural responses to emotional stimuli and could contribute to the understanding of mechanisms underlying the gender disparity of neuropsychiatric diseases such as mood disorders.

INTRODUCTION

Although several studies have shown that female and male subjects process emotions differently, with women being more emotionally expressive and showing stronger psychophysiological responses to emotional stimuli than men (Kring & Gordon, 1998), so far only few brain imaging studies have directly addressed the underlying functional anatomy of these phenomena. Most of these studies have examined gender differences in brain activation during the perception of facial expressions or emotionally salient pictures. Overall, in women the processing of emotion more frequently activated midline limbic structures, including the subcallosal anterior cingulate, thalamus, midbrain and cerebellum, whereas males showed more activation in left inferior frontal and posterior cortices (Mayberg *et al*. 1999; Wager *et al*. 2003; Habel *et al*. 2005).

Previous studies, using emotionally salient words and functional neuroimaging, have reported activation of frontotemporal areas, the

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subgenual and posterior cingulate cortex, the cerebellum, and subcortical structures (Fossati *et al*. 2003; Maddock *et al*. 2003; Schirmer *et al.* 2004). However, most of these studies did not consider the influence of gender on emotional perception and processing. Schirmer *et al.* (2004) investigated the brain regions that mediate the processing of emotional speech in men and women by presenting verbs with a positive or negative meaning that were spoken with happy or angry prosody. Participants were asked either to judge word valence while ignoring prosody, or to judge emotional prosody while ignoring word valence. The left inferior frontal gyrus was more strongly activated in incongruous as compared to congruous trials. This effect was significant in women whereas it was only apparent at a trend level in men. The authors suggested that semantic processing in women is more susceptible to influences from emotional prosody than is semantic processing in men. Shirao *et al.* (2005*a*) found that the bilateral caudate nuclei and left putamen were more strongly activated in women than in men while performing an emotional decision task with unpleasant words concerning interpersonal relationships, while the paralimbic area was activated only in women and the left medial prefrontal cortex was activated only in men while performing an emotional decision task with unpleasant words concerning body image (Shirao *et al.* 2005*b*).

We have recently investigated gender-related cerebral activation patterns during processing of affectively positive and negative visual stimuli taken from the International Affective Picture System (IAPS) (Lang *et al.* 1988) with event-related functional magnetic resonance imaging (fMRI) (Hofer *et al.* 2006). Depending on the emotion induced, women showed significantly greater activation in the right posterior cingulate, the left putamen and the left cerebellum during positive mood induction, and in bilateral superior temporal gyri and cerebellar vermis during negative mood induction, compared to men. To examine the potential influence of the type of emotional stimulus on gender-specific cerebral activation patterns, we performed the present fMRI study in the same sample using emotionally arousing nouns instead of pictures to elicit positive and negative emotions. Based on previous findings we predicted that the perception of positive emotions would lead to an activation of the prefrontal cortex in both sexes, which would be greater in the left than in the right hemisphere, while the perception of negative emotions would lead to the opposite activation pattern. Furthermore, we predicted that the perception of emotions would lead to a greater activation of the basal ganglia in females.

METHOD

Subjects

The subjects were 19 male and 19 female healthy volunteers (20–48 years old) of comparable ages [mean (S.D.): men = 34·11 (8·43), women = 31·84 (8·94), $p = 0{\cdot}43$] and education [mean (S.D.): men = 14·53 (2·38), women = 13·58 (2·77), $p = 0{\cdot}27$]. A brief medical screening interview was used to exclude subjects with any physical or neurological illness or any condition or medication affecting neural or cerebrovascular function. In this context, urine drug screens were performed as well as pregnancy tests in female subjects. Psychiatric disorders were excluded by using the Mini-International Neuropsychiatric Interview (M.I.N.I.; Sheehan *et al.* 1998). All subjects were right-handed (> 80 %), as measured with the Edinburgh Handedness Scale (Oldfield, 1971). After complete description of the study to the subjects, written informed consent was obtained. The study was approved by the local ethics committee.

Procedure

For stimulus presentation we applied a mixed design in which a block of either positively valenced words and non-words or a block of negatively valenced words and non-words was presented in a pseudo-random rapid event-related format. We presented emotionally arousing positive (e.g. freedom, love, vacation) and negative (e.g. death, fear, war) nouns (word length 3–8 letters), with a presentation time of 1 s and a jittered interstimulus interval (ISI) between 1·5 and 4·5 s to allow a linear estimation of the haemodynamic response (Miezin *et al.* 2000). The stimuli were taken from the *Häufigkeitswörterbuch gesprochener Sprache* (Ruoff, 1990), a lexicon of spoken German. As there is no set of German-language verbal materials that have been rated in terms of pleasure, arousal and dominance, the stimuli were picked out from the *Affective Norms for English Words* (ANEW; Bradley & Lang, 1999), which complements the IAPS. The stimuli were translated and their frequency in the German language was checked in the *Häufigkeitswörterbuch gesprochener Sprache*. Neuroimaging studies using emotional words have typically compared them with neutral words matched for length and frequency of usage. However, additional features of words may influence neural processing. For example, Rubin (1980) factor analysed 51 properties of words and identified six underlying factors, represented by length, imagery, familiarity, emotional valence, emotional arousal, and ease of recall. Therefore, to emphasize emotional verbal content, the control condition of the present study consisted of meaningless, but readable, non-words matched for length.

Within a measurement run, 40 words (positive or negative; activation condition) and, as a reference condition, 40 non-words were presented in a pseudo-random order. There was a 50% probability for each stimulus to occur. Sequential ordering was also ensured so that test and reference stimuli followed each other equally often. The ISI was chosen randomly starting from the scan onset time and varied in length to optimize the estimation of the event-related haemodynamic response. The rates of stimulus presentation and presentation time were chosen to give subjects ample time to make a response to each stimulus before the presentation of the subsequent stimulus. Stimulus material was projected onto a screen placed in front of the MRI scanner, visible to the participant by means of an angled mirror, placed above the head coil. During the ISI the screen was black. Following Schneider *et al.* (2000), the instructions were as follows: 'During this task, we would like you to try to become happy (sad). To help you do that, we will be showing you words with positive (negative) content. Look passively at each word and use it to help you to feel happy (sad)'. Subjects were asked to respond to each stimulus by a right- or left-index (activation and reference conditions respectively) press on a response device as soon as possible.

To avoid the order effect as well as carry-over effects in the scanning sessions, the sequence of stimulus presentation was counterbalanced for subgroups of subjects; that is, in half of male and female subjects positive mood was induced in a first run and negative mood in a second run and vice versa. The second run was administered in the scanner, 5 min after the first run.

Data acquisition

Subjective responses

The dependent measure for quantifying the mood induction effect was the Positive and Negative Affect Schedule (PANAS; Watson *et al.* 1988), a five-point unipolar intensity scale that includes 20 items for factor-referenced emotional descriptors for orthogonal positive and negative emotions. This was rated at baseline and after each presentation block (e.g. after the presentation of the 40 positive words and 40 non-words).

fMRI

Scanning was performed on a 1·5 T (Magnetom Vision, Siemens, Germany) MR scanner with a gradient rise time of 300 μs and a gradient strength of 25 mT/ms, using a circular polarized head coil (field of view 250 mm). For functional imaging, a T2-weighted single-shot echo-planar sequence was used (echo time 66 ms, echo spacing 0·96 ms, repetition time 3 s, matrix 64 × 64, slice thickness 5 mm with an interslice gap of 1·25 mm, voxel dimension $3{\cdot}91 \times 3{\cdot}91 \times 5\ \text{mm}^3$, flip angle 90°). Blood oxygen level-dependent (BOLD) contrast-sensitive images were acquired as a volume of 24 axial slices parallel to the bicommissural plane. The trigger signal from the scanner, the button press of the subject and the onset of the stimuli were recorded to the nearest millisecond on a separate computer. The first five images of each functional measurement were discarded from the analysis to allow for a stable MR signal.

Data analysis

Subjective ratings

The mood induction effect was quantified with the positive and negative scores of the PANAS. The scores were analysed in two separate repeated measures analyses of variance (ANOVAs), one for positive and one for negative PANAS scores. Mood induction (positive, negative) served as a repeated factor in the analyses, and gender as a between-subjects factor.

Table 1. *Emotional self-ratings assessed with the Positive and Negative Affect Schedule (PANAS) (mean ± S.D.) of 19 healthy males and 19 healthy females following happy and sad mood induction*

Condition	Total sample	Males	Females	Males *versus* females
PANAS positive score				
Baseline	29·5 ± 7·7	31·3 ± 6·7	27·7 ± 8·3	N.S.
Positive words	32·0 ± 7·6*	32·4 ± 7·5	31·6 ± 8·0*	N.S.
Negative words	28·0 ± 7·6	28·8 ± 8·2	27·2 ± 7·2	N.S.
PANAS negative score				
Baseline	13·4 ± 3·9	12·2 ± 2·2	14·5 ± 9·5	N.S.
Positive words	11·8 ± 2·5††	11·6 ± 2·2	12·0 ± 2·8††	N.S.
Negative words	15·1 ± 5·0*	13·7 ± 3·9	16·5 ± 5·7	N.S.

* Significantly higher score than for baseline condition ($p \leqslant 0·05$).
†† Significantly lower score than for baseline condition ($p \leqslant 0·01$).
N.S., Not significant.

fMRI analysis

Image analysis was performed offline on a PC using Matlab 5·3 and the SPM99 statistical parametric mapping software (Wellcome Department of Cognitive Neurology, London, UK). The functional images of each participant were automatically realigned to the first image of the time series to correct for head movement between scans. The individual high-resolution anatomical scan of each participant was co-registered to the functional images and normalized to the template of the Montreal Neurological Institute (MNI) – an average of 152 brains provided with SPM99. The parameters computed from this normalization were used to normalize the functional images. The functional data were then smoothed with a Gaussian kernel of 8 mm full-width at half-maximum (FWHM). The stimulus onsets of the trials for each condition were convolved with the canonical form of the haemodynamic response function (hrf) as defined in SPM99 and its temporal derivative (hrf). Low-frequency artefacts were removed with high-pass filtering (1/50 Hz) of the time series of images. Statistical inferences were drawn on the basis of the general linear model as implemented in SPM99. Linear contrasts were calculated for the comparisons between conditions. The contrast images were then entered into a second-level analysis (random effects model) to extend statistical inference about activity differences to the population from which the participants were drawn. Activations are reported for clusters of eight contiguous voxels that surpassed an initial uncorrected threshold of $p<0·001$ and had a corrected p value of $p<0·05$ on cluster level. The coordinates given by SPM99 were corrected to correspond to the atlas of Talairach and Tournoux (1988). We did not directly compare the brain activation patterns associated with the processing of positively *versus* negatively valenced words as they were not matched for arousal and valence.

RESULTS

Subjective ratings

Mean scores and standard deviations for the PANAS subscales are presented in Table 1. During positive mood induction, both the positive and the negative score of the PANAS did not change significantly in men. By contrast, there were significantly higher scores of positive affect ($p=0·017$) and a statistically highly significant reduction in negative affect ($p=0·007$) in women. During negative mood induction, neither sex showed any change in either positive or negative affect. However, there was an overall group significant effect of higher negative scores across the subjects following the negative words.

fMRI: positive mood induction > reference condition

Except for an activation of the right cerebellum, positive signal changes were located in the left hemisphere (sensorimotor cortex, angular gyrus, precuneus/posterior cingulate, frontal eye field, superior temporal gyrus and central cingulate) in the total sample. In men, positively valenced words activated the left sensorimotor

Table 2. *Brain regions associated with significant blood oxygen level-dependent (BOLD) signal increases during positive mood induction* versus *reference condition*[a]

Region	Brodmann's area	Coordinates[b] x	y	z	*Z* score
Total sample					
Left sensorimotor cortex	4/3/1/2/5/40	−36	−24	52	7·64
Left angular gyrus	39	−48	−56	16	5·08
Left precuneus/posterior cingulate	7/31	−12	−56	28	4·04
Right cerebellum		20	−56	−24	4·00
Left middle frontal gyrus	8/9	−28	24	44	3·81
Left superior temporal gyrus	42	−52	−20	8	3·47
Left central cingulate	24	−12	−12	48	3·43
Males					
Left sensorimotor cortex	4/3/1/2/40	−36	−24	52	5·14
Right cerebellum		20	−52	−20	4·20
Left angular gyrus	39	−48	−60	16	3·78
Left parahippocampal gyrus/hippocampus	35/36	−32	−32	−16	3·57
Retrosplenial cortex	29/30	0	−40	16	3·48
Left lingual gyrus/cerebellum	18	−20	−88	−20	3·40
Left middle frontal gyrus	8	−28	20	44	3·39
Females					
Left sensorimotor cortex	4/3/1/2/40	−44	−24	56	6·01
Left angular gyrus	22/39	−52	−56	16	3·51
Left precuneus/posterior cingulate	7/31	−16	−44	32	3·41
Males – Females					
No significant BOLD signal increases					
Females – Males					
Right putamen		28	8	−4	3·38
Right superior temporal gyrus	38/22	48	−12	−4	3·21
Left supramarginal gyrus	40	−44	−44	32	3·18

[a] Estimated Brodmann's areas and coordinates from Talairach & Tournoux (1988); *Z* scores represent peak activation in the cluster.

[b] The cluster with the largest number of voxels within each region is reported. Talairach coordinates refer to the voxel with the maximum fundamental power quotient in the cluster.

cortex, angular gyrus, perirhinal cortex/hippocampus, lingual gyrus/cerebellum as well as the frontal eye field and the right cerebellum, compared to the reference condition. A further midline activation was detected in the retrosplenial cortex. Women showed a significant left hemispheric BOLD response in the sensorimotor cortex, the angular gyrus and the precuneus/posterior cingulate (see Table 2).

When subtracting the activation values of men from those of women, females had relatively greater activation in the right putamen, the right superior temporal gyrus and the left supramarginal gyrus when positively valenced words were presented (Table 2, Fig. 1). The subtraction of activation values of women from those of men yielded no significant differences.

fMRI: negative mood induction > reference condition

Activation was seen in the left sensorimotor cortex, inferior frontal gyrus (triangular part) and supramarginal gyrus, and in the right cerebellum in the total sample. In men, positive signal changes were detected in the left sensorimotor cortex, supramarginal gyrus, thalamus and posterior cingulate as well as in the right cerebellum. By contrast, women activated the left sensorimotor cortex and inferior frontal gyrus (triangular part) (see Table 3). The direct comparison between men and women revealed suprathreshold positive signal changes in the left perirhinal cortex and hippocampus for women *versus* men, while men showed relatively greater activation in the right supramarginal gyrus (Table 3, Fig. 2).

DISCUSSION

In the present study, we used positively and negatively valenced words to examine the brain areas engaged in emotional processing and to compare the pattern of brain activation between female and male subjects. Our finding of

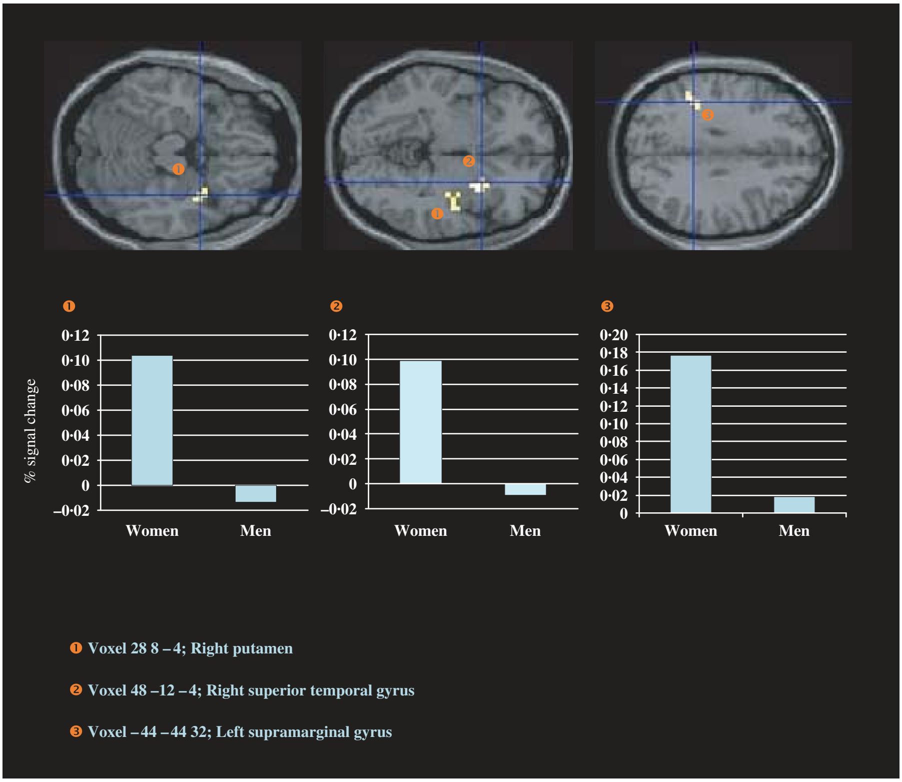

FIG. 1. Horizontal sections showing significant differences between females and males + percentage signal change in change of cerebral activity during positive mood induction (values for females minus values for males). Coloured areas exceed a p value of 0·05 (corrected at cluster level) with eight or more contiguous voxels activated. For localization of activation, see Table 2.

left-lateralized activation of the motor system in both males and females suggests that the networks controlling left and right are not necessarily the same. However, as activation of the motor network does not seem to be associated with the perception of emotion, it is not discussed further in this paper.

As the response fingers (right index – activation condition, left index – reference condition) were not counterbalanced for subgroups of study participants, at least some portions of the significant activation found in the contrast between male and female subjects could have been due to gender differences in neural circuitry controlling motor responses rather than that in emotional neurocircuitry. For instance, Bell *et al.* (2006) have reported on an increased BOLD signal magnitude in the right inferior parietal gyrus and in the left inferior frontal gyrus in males compared to females during the performance of a right-hand motor task.

When interpreting our data, consideration should be given to the fact that only the presentation of positively but not negatively valenced words yielded affective changes in female subjects, whereas our male subjects did not report any significant affective changes during stimulation with either positively or negatively valenced words. By contrast, while viewing emotionally positive pictures, the male subjects investigated in this study had shown a trend towards a reduction in the negative score of the PANAS, while the positive score had remained unchanged (Hofer *et al.* 2006). In women, on the contrary, there was a trend to higher scores of positive affect and a statistically significant reduction in negative affect. During stimulation with pictures of emotionally negative content, negative affect was increased in both sexes, while positive affect remained unchanged in women and slightly decreased in men (Hofer *et al.* 2006). Behavioural studies have

Table 3. *Brain regions associated with significant blood oxygen level-dependent (BOLD) signal increases during negative mood induction* versus *reference condition*[a]

		Coordinates[b]			
Region	Brodmann's area	x	y	z	*Z* score
Total sample					
Left sensorimotor cortex	4/3/1/2/5/6/40	−40	−24	52	7·59
Left inferior frontal gyrus	45/46	−40	40	8	4·82
Right cerebellum		12	−56	−20	4·28
Left supramarginal gyrus	40	−60	−44	24	3·23
Males					
Left sensorimotor cortex	4/3/1/2/5/40	−40	−24	52	5·90
Right cerebellum		12	−56	−16	5·16
Left supramarginal gyrus	22/40	−44	−48	20	4·71
Left thalamus		−20	−20	0	3·66
Left posterior cingulate	31	−12	−28	48	3·42
Females					
Left sensorimotor cortex	3/3/1/2	−28	−20	68	5·19
Left inferior frontal gyrus	45/46	−40	40	8	4·48
Males – Females					
Right supramarginal gyrus	39	36	−56	28	3·06
Females – Males					
Left parahippocampal gyrus/hippocampus	35/36	−36	−28	−12	3·18

[a] Estimated Brodmann's areas and coordinates from Talairach & Tournoux (1988); *Z* scores represent peak activation in the cluster.

[b] The cluster with the largest number of voxels within each region is reported. Talairach coordinates refer to the voxel with the maximum fundamental power quotient in the cluster.

shown that a picture is more likely to be remembered than the presentation of the word describing this picture (a finding known as the picture superiority effect). The implication is that pictures are associated with both non-verbal (image-based) and verbal codes whereas words are only associated with a verbal code (Paivio & Csapo, 1973). Nevertheless, in the present study stimulation with emotionally salient words yielded changes in cerebral activation patterns in both sexes. However, when interpreting our findings, the possible confounders of semantic processing should be considered (e.g. Martin, 2003).

We cannot exclude the possibility that an additional mental process during the reference condition (i.e. trying to make sense of the meaningless non-words) could have had an influence on brain activation found in the contrast of activation *versus* reference condition. In addition, possible sex differences in language abilities should be considered, with women having better linguistic abilities than men. Whether sex differences emerge at a neural rather than just at a behavioural level is still under debate. The available neuroimaging studies provide conflicting results that can be attributed to the complexity of variables influencing cognitive sex differences. Sex differences were found in the inferior frontal gyrus during phonological and syntactical tasks and in the posterior language areas during passive listening to spoken narrative. However, some studies have not found sex differences during various language tasks, including verb generation, word completion or semantic word judgment (Weiss *et al.* 2003).

During stimulation with positively valenced words, both male and female subjects activated the left angular gyrus and the left posterior cingulate cortex, and men further activated the left frontal eye field. Mesulam (1999) has proposed the existence of a distributed large-scale network responsible for allocating attentional resources to novel objects in the visual field. This attentional network is said to consist of three cortical epicentres: the posterior parietal cortex, the frontal eye fields, and the cingulate gyrus. The parietal component of the network creates a salience map of the external world that is used by the frontal component to preferentially allocate attention to the various novel stimuli located on the map. The cingulate gyrus then extrapolates the motivational relevance of

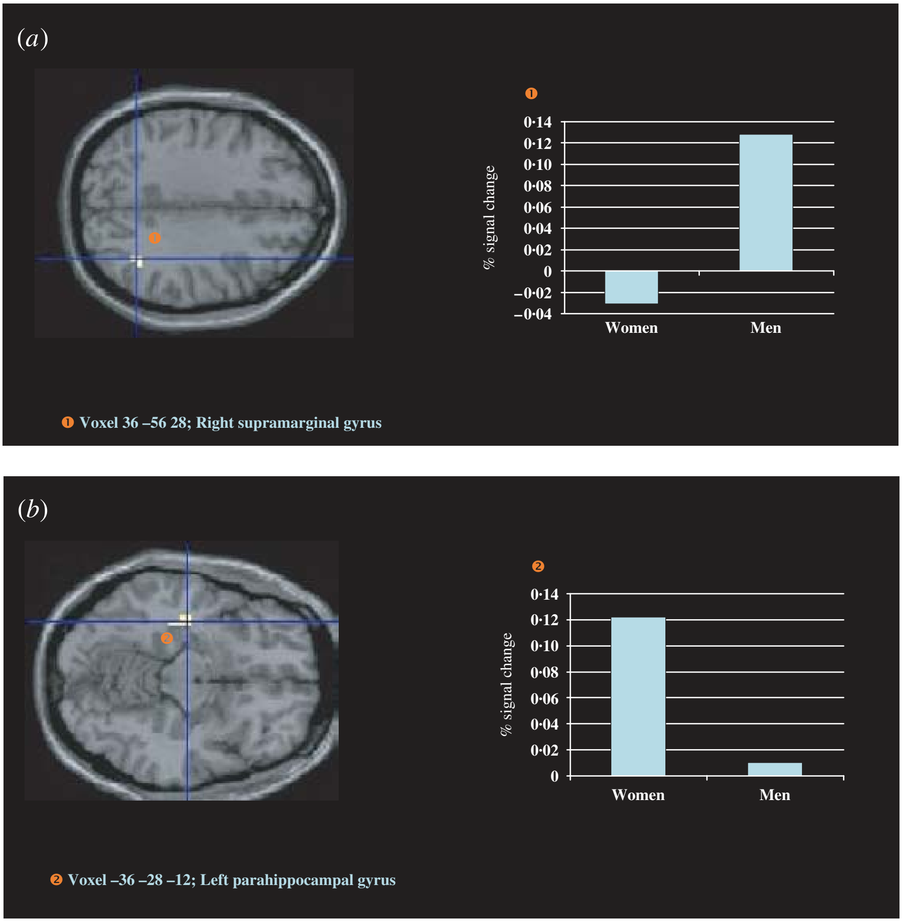

FIG. 2. Horizontal sections showing significant differences between females and males + percentage signal change in change of cerebral activity during negative mood induction: (*a*) values for males minus values for females; (*b*) values for females minus values for males. Coloured areas exceed a *p* value of 0·05 (corrected at cluster level) with eight or more contiguous voxels activated. For localization of activation, see Table 3.

each novel stimulus and sustains the level of effort needed for the execution of attentional tasks. Altered processing of affective stimuli makes the concept of a salience map particularly important. This notion may be especially relevant to the understanding of emotion processing in patients with neuropsychiatric disorders such as schizophrenia, Huntington's disease and Alzheimer's disease, all of whom show impairment in assessing the salience of certain affective stimuli in the external world.

Our demonstration of posterior cingulate activation is also in accordance with a meta-analysis by Maddock (1999) that has shown that the caudal part of the posterior cingulate cortex was the cortical region most consistently activated by emotional stimuli compared to nominally matched, emotionally neutral stimuli. It has also been hypothesized that the posterior cingulate cortex has a role in the modulation of memory by emotionally arousing stimuli (Maddock, 1999).

A direct comparison of brain activation between men and women revealed differential activation in the right putamen, the right superior temporal gyrus, and the left supramarginal gyrus during positive mood induction for women *versus* men. Our finding of a pronounced activation of the putamen in female as compared to male subjects corresponds to that of Shirao *et al.* (2005*a*), who used fMRI to investigate gender differences during the perception of unpleasant linguistic stimuli concerning interpersonal relationships. In addition, structural and functional abnormalities of the putamen and the superior temporal gyrus have consistently been associated with neuropsychiatric disorders. For example, Bielau *et al.* (2005) have reported on smaller volumes of the subcortical nuclei, including the putamen, in patients with mood disorders as compared to individuals without a neuropsychiatric disorder, and Surguladze *et al.* (2005), using fMRI, have demonstrated linear increases in response in the putamen to expressions of increasing happiness in healthy, but not depressed, individuals. Similarly, a reduced cerebral blood flow in the superior temporal gyrus has been detected in patients with persecutory delusion (Blackwood *et al.* 2001) and bipolar affective disorder (Mitchell *et al.* 2004) and has also been associated with mood fluctuations in patients with Parkinson's disease (Black *et al.* 2005).

Angular and supramarginal gyri form the inferior parietal lobule, a heteromodal association neocortical region that is part of the neuroanatomical circuitry for language comprehension (Mesulam, 1990). Previous functional neuroimaging studies (Sommer *et al.* 2001) have shown left lateralized activation of these areas in subjects performing language tasks. Sex differences in language abilities have long been hypothesized, with women performing better on tasks involving receptive and productive language (Weiss *et al.* 2003). These behavioural differences have been suggested to relate to differences in brain lateralization, with men performing better than women on certain spatial tasks because of their greater lateralization for these tasks in the right hemisphere, and women performing better than men on some verbal tasks because these functions are represented bilaterally in the brain (Gur *et al.* 2000).

Besides the reported activations, men showed additional BOLD signal increases in the left perirhinal cortex/hippocampus and the cerebellum during positive mood induction. Again, neuroimaging studies of patients both with schizophrenia and major depression have shown several abnormalities of regional cerebral blood flow and glucose metabolism in various brain regions, including the limbic cortex and the hippocampus (Gur *et al.* 2002; Kalia, 2005), and the cerebellum is also known to be involved in emotion processing (Schmahmann, 2000).

During stimulation with negatively valenced words, male subjects again activated parietal, posterior cingulate and cerebellar regions, but also the thalamus. This is consistent with the findings of Canli *et al.* (2002) and Lee *et al.* (2005) and may relate to the subcortical integration of visceral responses and emotional arousal for further interaction with cortical regions (Canli *et al.* 2002). By contrast, in women positive signal changes were detected in the triangular part of the left inferior frontal gyrus, which might reflect increased demands on the subvocal rehearsal component of the working memory system (Poeppel, 1996).

Besides relatively greater activation in the left perirhinal cortex/hippocampus for women *versus* men, the direct comparison of brain activation during negative mood induction revealed relatively greater activation in the right supramarginal gyrus for men *versus* women, a region that has recently been shown to be activated when observing hand actions performed in an angry way (Grosbras & Paus, 2006). Our result therefore suggests that the supramarginal gyrus plays an important role in the processing of negative emotions regardless of the sort of stimulus, whether it is verbal or non-verbal. Furthermore, with regard to the often reported gender differences concerning depressive disorders, in which behaviours such as aggression and violence are usually attributed to men and termed 'masked depression', this greater activation observed solely in male subjects in our experiment may indicate a neurobiological substrate for the 'male depressive syndrome' proposed by Walinder & Rutz (2001) comprising low stress tolerance, acting-out behaviour, low impulse control, substance abuse, and suicide.

In summary, this report contributes to the groundwork for unlocking the neuroscientific basis of emotional functioning in men and women. It also indicates that consideration must be given to gender in future studies of emotional processing.

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DECLARATION OF INTEREST

None.

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