Event-Related Desynchronisation of 8-13Hz cortical oscillations during perception of negative, positive and neutral (emotional) stimuli in males and females.

Farthing, N., Lord, E., & Stancak, A., (2010)

Abstract

The present study examined the differences between men and women in emotional processing, particularly the cortical oscillatory changes of 8-13Hz that occur during viewing affective stimuli. Previous areas of research have found asymetrical responses in the frontal lobes and the right parietal lobe in terms of valence discrimination. In respect of gender differences, males show greater activation for positive stimuli, while women exhibit stronger activation for negative stimuli. In the present study, 128 channel EEG was used in 12 male and 12 female subjects to extract Event-Related Desynchronisation (ERD) responses. The standardized visual stimuli used was randomised to eliminate possible anticipatory associations, and each image was contained in an epoch of 11 seconds to allow for pre and post stimulus and for cortical rhythms to return to a resting state. The Self Assessment Manikin (SAM) and State Trait Anxiety Inventory (STAI) were used to examine a correlation with cortical activity. Males demonstrated greater ERD than women across all conditions with greater frontal symmetry, with structures that included the medial frontal gyrus, the cingulate gyrus and the precuneus. Women showed occipital activation, responding more to negative images, and employed structures such as the insula, posterior cingulate, superior frontal and superior temporal gyrus and parahippocampal area; mainly Right lateralised. Self-reports and subjective ratings did not show any significant differences between the genders. Findings reported here suggest that males exhibit stronger ERD responses to emotionally salient stimuli compared with females, and that men and women use different cortical areas. It appears that both genders may engage in ongoing appraisal of emotionally salient stimuli. Top-down processing of emotionally affective images may be employed by both genders.

Introduction

Current models of emotional processing

Neuropsychological findings primarily posit two distinct models of emotional processing. The Right Hemisphere (RH) Model proposes that emotionally salient stimuli is processed predominantly in the RH, with no evidence that each hemisphere is responsible for processing different types of emotion (Ley & Bryden 1982). Research points to RH activation in several negative-affective situations (Otto, Yeo & Dougher 1987), particularly depression. In contrast, the Valence Theory favours a positive-negative dichotomy where the left hemisphere (LH) is instrumental in processing positive emotions with the RH processing negative emotions (Davidson, Eckman, Saron, Senulis, Friesen 1990). More recent research by Balconi and Mazza (2009) has not shown convincing support for either model, but has interestingly purported that unconscious versus conscious processing could explain observed hemispheric lateralisation; that RH processes unconsciously and the LH processes consciously and this could explain a prevalence of RH activation more so than LH activation. Findings differ dependent upon the experimental paradigm; verbal emotionally-affective cues appear to be processed by different mechanisms and induce a lateralisation in opposition to the valence theory (Hirata, Koreeda, Sakihara, Kato,Yoshimine, & Yorifuli, 2007).

Gender differences in emotional processing

Overall, neuroimaging studies have summarised areas of the brain consistently involved in emotional processing. In the paralimbic region, the ventro-medial pre frontal cortex, (vmPFC), lateral orbito-frontal cortex (OFC), and the anterior insula (aINS) are reliably activated, with stimulation of the anterior cingulate cortex (ACC) in the rostral region predominantly. Also, the occipital areas and the superior temporal sulcus (STS) and superior temporal gyrus (STG) are highly implicated (Wager et al 2008). Whilst there may be an ‘expectation’ to observe these areas in evoking emotional responses, it is a question of what, if any gender differences exist, and the relation to the valence of the stimulus.

When encoding emotionally salient stimuli, men and women have been found to employ different cortical structures, despite subjective ratings considering the images as equally arousing (Canli, Desmond, Zhao & Gabrieli 2002). This study found that males employed more cortical structures than women, but that the female subjects had more brain regions that appraised the stimuli progressively. Also, the right amygdala was implicated with male subjects, whereas the left amygdala was activated in the female cohorts. Conversely, for facial affect, it has been found that the amygdala activates bilaterally for males and females in emotional processing, but that the direction differs between valence conditions (Killgore, & Yurgelun-Todd 2001).

Many EEG and neuroimaging studies have used The International Affective Picture System (IAPS) (Lang, Bradley & Cuthbert 2008) to elicit emotional correlates in gender based experiments. As it contains standardised visual stimuli, it is considered a robust tool for examining emotional responses. Wrase, Klein, Gruesser, Hermann, Flor, Mann, Braus, & Heinz (2003) used fMRI and with standardized visual stimulus and found that amygdala activation only occurred with men in the pleasant condition. Men also showed stronger brain activity for positive stimuli than women in the frontal lobe areas encompassing the inferior and medial frontal gyrus, whereas women showed greater activation for negative stimuli activating the anterior and medial cingulate gyrus. Women have been found to process emotional information in a manner consistent with the valence hypothesis (Canli, Desmond, Zhao, Glover, Gabrieli 1998), and to produce greater asymmetry with regards to positive affects than males (Meyers & Smith 1987). In the occipito-temporal areas, men have shown an asymmetric lateralisation, whereas women have demonstrated bilateral activity (Proverbio, & Brignone 2006).

These findings infer a contrast between the genders in emotional processing networks and it is suggested that an overlap in brain regions associated with memory may account for this disparity as it is suggested that women encode emotional experiences in more detail than men (Seidlitz & Diener 1998). Other suggestions claim that emotional intelligence accounts for the observed gender differences, stating that women outperform men in some areas of emotional processing (Mayer, Caruso & Salovey 2000). However, more recent research points to no gender superiority in emotional processing abilities with parity of subjective emotional ratings for men and women (Freudenthaler, Fink & Neubauer 2006), (Jausovec & Jausovec 2005). The plethora of data thus far does suggest a similarity in males and females in terms of intellectual performance, but that different neuroanatomical structures are employed which may be owing to women using more neuronal processes but fewer neurons than their male counterparts (Jausovec and Jausovec 2008), a phenomenon described as 'neural efficiency hypothesis'.

Event-Related Desynchronisation (ERD) and Electroencephalography (EEG)

Investigating complex behaviours such as emotion, has led to a diverse experimental research area where various techniques such as fMRI, MEG and EEG are used in conjunction with a multiplicity of stimuli encompassing written expression, verbal expression, affective tasks and viewing pictures. Such measures take a differing view of brain activity, however EEG has superior temporal resolution when examining cortical activity. Evoked potentials are the sums of several phase-locked components that are generated in different cortical areas at different times and are reflected as positive and negative fluctuations associated with periods of excitation and inhibition (Kropotov 2009).

Event-Related Desynchronisation (ERD) (Pfurtscheller & Aranibar 1977) fluctuation associated with awareness has been evidenced as a robust indicator of localised brain activation in affective tasks. Further suitability stems from the capability of ERD to detect relatively small changes in processing, thus making it a suitable medium for studying emotional processing (Aftanas, Koshkarov, Pokrovskaja, Lotova & Mordvintsev 1996b).

<u>ERD in affective processing</u>

Pfurtscheller (1992) discovered that ERD started in the occipital area 1 second prior to stimulus onset of a voluntary movement, possibly indicating an anticipatory response. An anticipatory paradigm has found alpha ERD for negative emotional stimuli compared to positive emotional images to be not only greater preceding the image, but also to show occipital dominance. The effect was mirrored in the upper alpha band in the frontal RH area (Onoda, Akamoto, Shishida, Hashizume, Ueda, Yamashita & Yamawaki 2007). It was suggested that these findings indicated a top-down modulation from right frontal cortex to the visual cortex.

<u>Alpha rhythm 8-13Hz</u>

A relaxed waking state is the usual and optimal status for the posterior alpha rhythm, and it is assumed that emotional stress or anxiety could attenuate the alpha rhythm Niedermeyer (2004). The alpha rhythm is typically blocked by attending to visual stimulus or cognitive processing and whilst alpha shares the same frequency range as the rolandic mu rhythm, its mapping and reactivity is different. The spatial distribution of alpha is typically over the occipital, parietal, and posterior temporal regions with some activation occurring in mid-temporal areas. The central region can be implicated in Alpha rhythm, but must be differentiated from the rolandic mu rhythm, particularly in the motor cortex region (Neidermeyer 2004). Blocking the alpha rhythm thus leads to a desynchronisation (Event-related Desynchronisation; ERD) of the voltage activity. In averaging these ERDs, it is possible to elicit cortical maps of activity to investigate neuronal processes (Pfurtscheller & Lopes da Silva 1999).

In dividing the alpha band, it may highlight the sensitivity of EEG, and particularly ERD. Aftanas et al (1996b) were able to extrapolate an increase in ERD in response to negative stimuli which manifested in the right mid-frontal region when compared to the left region. Both the RH and the LH participated in valence discrimination which supported the valence theory of emotional processing. Furthermore, they concluded that the alpha band yielded differences between the 8-10Hz and 10-12 Hz widths in respect of affective processing suggesting that no single alpha rhythm is responsible but a variety of alpha frequencies (Aftanas, Koshkarov, Pokrovskaja, Lotova & Mordvintsev 1996c).

Klimesch (1999) found that different patterns of alpha ERD were observed when the band was subdivided with the lower band reflecting attentional processes and the upper, more complex demands. As a result, it was suggested that broad band analyses of electrophysical brain activity could possibly obscure any frequency specific effects.

The lower-2 alpha band has shown robust gender dimorphism in emotional processing (Jausovec & Jausovec 2008) in the frontal cortical areas underpinning the attentional processes at work (Klimesch 1999). Jausovec and Jausovec (2008) suggest that males generally show more activation in the frontal areas and with women showing more activity on parieto-occipital areas. They admit to a vague speculation that this may be due to males being more analytical in their deliberations where women are more intuitive.

The present study uses EEG to measure ERD in response to attending standardized visual stimuli. A simplistic approach will allow for the stimuli to be classified with respect to arousal and valence in negative, positive and neutral conditions. The International Affective Picture System (IAPS) (Lang, Bradley and Cuthbert 2008) is a reliable and standardized method to induce and measure emotions with respect to these dimensions. In order to extrapolate neuroanatomical correlates of emotion, this paradigm focuses on affective processing as opposed to cognitive processing; the observed epoch of 1s pre-stimulus and 4s post-stimulus does not require any imposed task. As a consequence, the broad band of 8-13Hz will be examined.

A between and within subjects design was used to test examine whether EEG patterns will differentiate during viewing affective images of different valence and arousal, using event-related desynchronisation (ERD) from EEG recordings. This design will compare and examine the 8-13 Hz Alpha rhythms in healthy male and female volunteers viewing neutral, negative and positive images from the IAPS (Lang, Bradley and Cuthbert 2008). Subjective ratings of valency and arousal using the Self Assessment Manikin (SAM) (Bradley & Lang 1994), and self-reports of anxiety using the State Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch & Lushene 1970) will be examined for a correlation with cortical activity.

Method

Participants

An opportunity sample of healthy participants was selected, N=21. These were placed into two groups based on their gender. Group 1 (N=10) were the female participants and Group 2 (N=11) were the male participants. Group 1 mean age= 27, SD=7.53. Group 2 mean age=21, SD=2.27. All participants reported normal or corrected to normal visual acuity and no history of neurological or psychiatric illnesses. This study was conducted according to a protocol approved by the University of Liverpool Ethics Committee. Participation in this experiment was voluntary and written consent was obtained from each participant prior to the experiment. The majority of participants received credit through the undergraduate EPR scheme in exchange for their participation. Others were recruited through opportunity sampling.

Materials and Procedure

A bank of visual stimuli was constructed, comprising of 60 negative, 60 positive and 60 neutral images. Negative images included human injury, fearful situations and aggressive animals. Positive images included babies, weddings, smiling faces and family events. Neutral images included images such as household items and landscapes. Images were selected from the International Affective Picture System (IAPS) Lang, Bradley and Cuthbert (2008) based on their normative valence ratings. These images were then randomized into six separate blocks consisting of 30 mixed images in each block. The timeframe for each image would be an epoch of 11000 milliseconds; 4000 milliseconds resting state, 3000 milliseconds of image display, 2000 milliseconds for oscillations to return when a question mark appeared as a cue for the participant to rate the photograph, and 2000 milliseconds for the participant to record their response. Participants were instructed to keep their eyes and body still, trying not to blink and to concentrate on the centre of the screen before, during and immediately after the presentation of the stimulus, to reduce artifacts.

All trials consisted of the same basic structure; age, gender and handedness of the participants were recorded. Images were viewed on a colour monitor from a distance of 1 metre. All stimuli presented on the monitor were the same size with the same background and brightness. Participants were given a key pad to register their responses to the stimulus as neutral, positive or negative to maintain engagement throughout.

Behavioural data

Following on from viewing the images, participants then rated the same images using a computerised SAM Manikin scale (Bradley & Lang 1994), in order to record their subjective ratings of valence and arousal. This was conducted to examine if any correlation would occur in respect of cortical activity and self-reporting. Participants then completed the State Trait Anxiety Intervention (STAI) (Spielberger, Gorsuch & Lushene 1970), questionnaire. The STAI encompasses a broad spectrum of anxiety characteristics considered either as 'State or 'Trait' which could highlight general anxiety traits that may influence emotional perception. The data from this measure would be evaluated to ascertain any behavioural characteristic having a covariate effect.

EEG recording and Quantification

A Geodesic EGI (Electrical Geodesics Inc.) was used to record EEG continuously with a 128-electrode array. The vertex was chosen as the reference electrode. As suggested for the EGI high input impudence amplifier, impedances were kept below 50 kΩ. Sampling rate (samples/seconds) was 250 Hz, and all channels were pre-processed on-line by means of 0.1- to 100-Hz band-pass filter. Initial visual assessment of the 8-13Hz band showed that there were stronger amplitude decreases during stimulus onset over two separate time epochs of 1-2(s) and 2-3(s) post-stimulus.

The critical timeframe for each image was an epoch of 0-1.5(s) of pre-stimulus resting state *(R)*; and 1.5-4.5(s) of image display for activation interval *(A)* for calculating ERD. The epoch covering the image display time was evaluated by contrasting the pre-stimulus and post-stimulus intervals for each type of stimulus. The resting band power was computed for reference and activation in each trial after squaring band pass filtered signals. The percentage decrease in 8-13Hz (μV^2) from the aggregated reference interval *(R)* to the aggregated activation interval *(A)* was defined as: %ERD = $([R - A]/R) \times 100$ (Pfurtscheller & Aranibar

1977). Positive %ERD values indicate decreases in alpha power consistent with cortical activation or desynchronisation (Pfurtscheller & Aranibar 1977).

The raw data from the changes in the 8-13Hz band were pre-processed using Brain Electrical Source Analysis (BESA 5.2, Megis Software, Germany) for source analysis and dipole localization. Following this, the grand average spectra were analysed across all trials, with the reference and activation intervals checked individually for movement and muscle artifacts by visual inspection. Any trials exhibiting artifacts were completely eliminated from the ERD analysis by way of visual analysis. In this instance, 3 subjects were excluded from further analysis due to large amounts of artefacts.

Cortical mapping

To localize the cortical origins of the 8-13Hz ERD, low-resolution electromagnetic tomography (LORETA) (Pascual-Marqui, Michel & Lehmann 1984) was used on one female and one male subject. The LORETA-Key program was applied to compute the maps (http://www.keyinst.unizh.ch). The 3D electrode positions were transformed to the Talairach co-ordinate system (Talairach and Tournoux 1988). The source mapped values were performed in 6239 voxels sized at 5x5x5 mm^3 covering only the cortex. In the female example, the mapped t values of ≥= 3.1 taken 2.250(s) at the point of stimulus onset were presented, and for the male example, the mapped t values of ≥= 3.1 taken 1.625(s) after stimulus onset were reported.

Results

Behavioural data

An independent t-test was conducted on the scores for both males and females in respect of the State Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch & Lushene 1970). In terms of State anxiety, males reported slightly more anxiety ($\bar{x}$=38, SD= 10.4) than females ($\bar{x}$=36.1, SD= 11.57). However, there was no significant difference found between males and females in terms of State anxiety (*t* (19)=.396; *p*=0.697). In respect of Trait anxiety, males reported slightly higher values ($\bar{x}$=41.63, SD= 12.99) compared with females ($\bar{x}$=40.9, SD= 9.5). No significant difference was found between males and females in terms of Trait anxiety (*t* (19)= .147; *p*= .885). Overall, no statistically significant difference was found between genders in terms of State and Trait anxiety.

Figure1A Mean Subjective Ratings for Valence

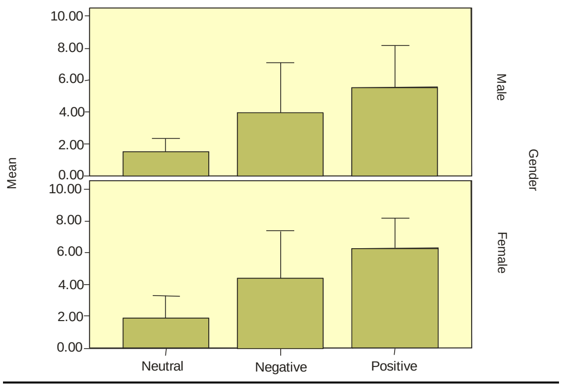


Figure 1B Mean Subjective Ratings for Arousal

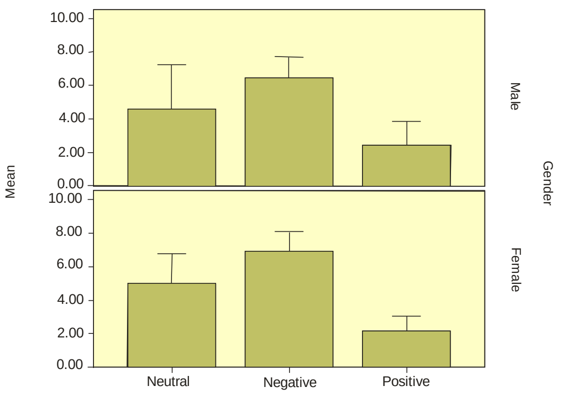


Figure 1A and Figure 1B demonstrate the mean subjective ratings of valence and arousal (SAM) respectively in all three conditions for both genders. In terms of valency, in the neutral condition ($\bar{x}$=1.71, SD= .59) lower arousal was reported than for both the negative condition 2 ($\bar{x}$=4.14, SD= 1.52), and the positive condition 3($\bar{x}$=5.91, SD= 1.18). Both genders reported greater arousal for emotional stimuli with the greatest value being in the negative condition. In terms of arousal, the negative condition 2 ($\bar{x}$=6.68, SD= .64) showed the greatest valence, with the positive condition 3 showing the least ($\bar{x}$=2.32, SD= .60) and the neutral condition 1 around the middle of the ratings ($\bar{x}$=4.79, SD= 1.14). The mean values in terms of valence and arousal for both genders demonstrate that three distinct conditions were successfully employed.

Figure 2 ERD Grand average

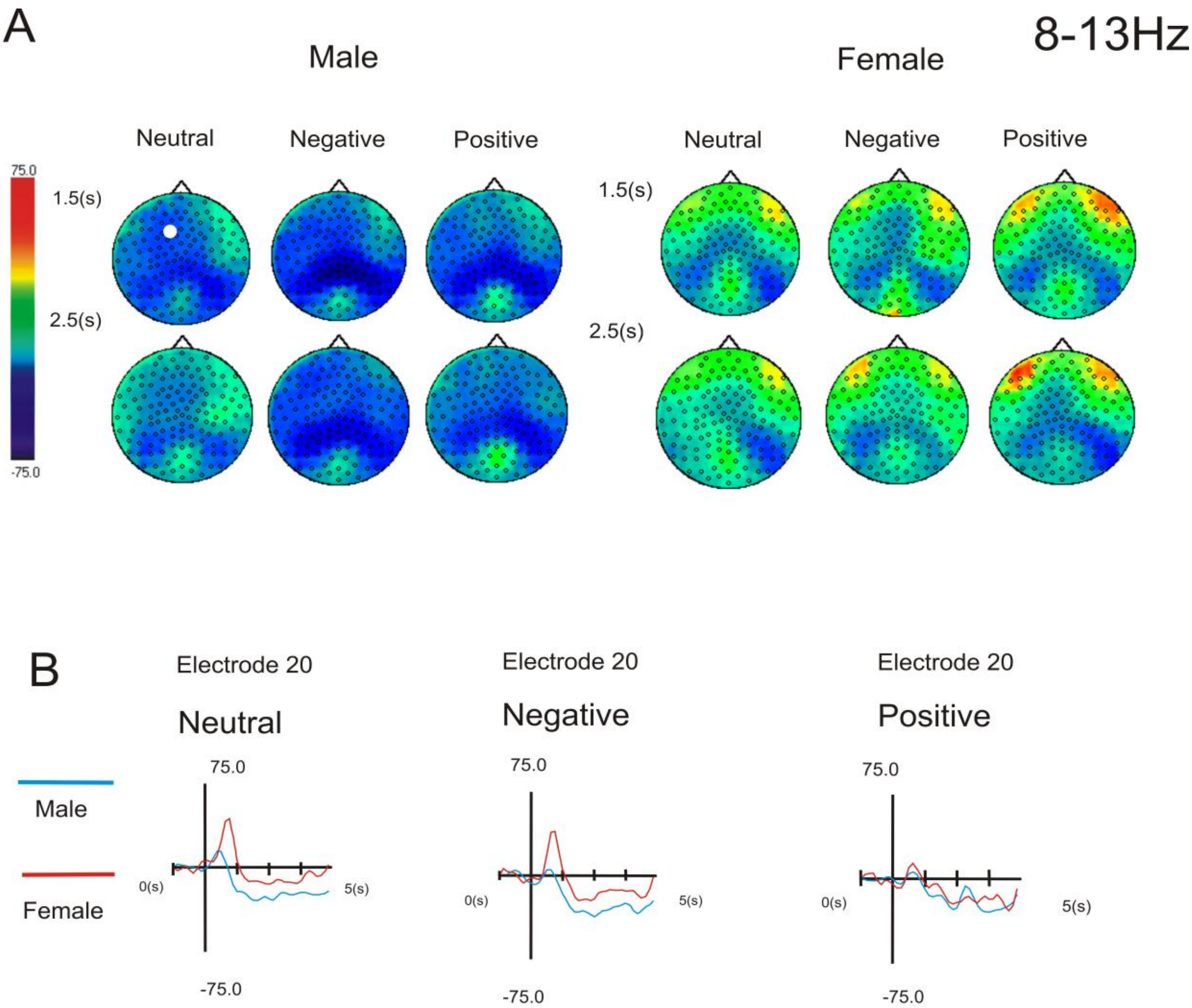


Figure 2A depicts the grand average spectra of ERD of male and female subjects across all 3 conditions in time frames of 1.5(s) and 2.5(s) post-stimulus. Electrode 20 is highlighted. Figure 2B depicts the comparison of the Grand average ERD response of the male and female subjects in each of the conditions and across the time interval of 0s to 5s at electrode 20.

The ERD 8-13Hz changes illustrated above, show that in Figure 2A, the male subjects demonstrate bilateral activation over both time epochs in all three conditions. This appears in frontal and temporo-parietal areas. Both the negative and positive conditions illicit the strongest activation compared to the neutral condition. The female subjects showed much less activation than the male example across all conditions and implicated less cortical areas. The occipital areas were activated bilaterally, with some activation shown in the parietal area.

A comparison of the ERD response of the example male and female subjects depicted in Figure 2B shows the time epoch of 0(s) to 5(s), stimulus onset to post-stimulus. It illustrates that the male's response was stronger with a greater desynchronisation when compared to the female subject.

Figure 3A.

Map of chosen electrode patches

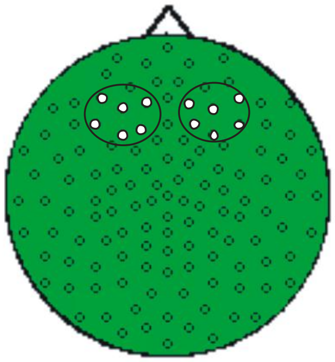
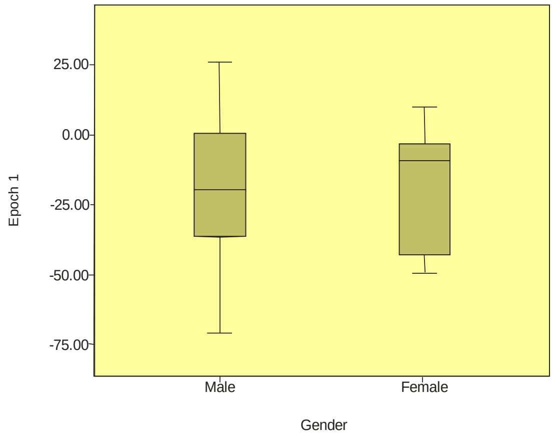


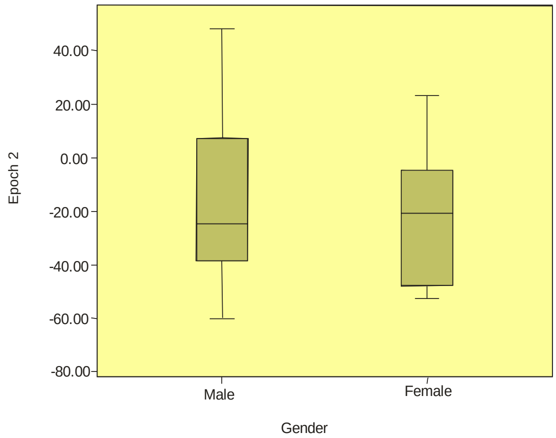
Figure 3A shows two patches of electrodes from which the ERD readings were the strongest. RH(patch1):2,3,4,10,123,124. LH(patch2):19,20,24,25,27,28.

Figure 3B boxplots showing mean averages of ERD recordings taken from both patches over time epoch 1 (1-2s) and time epoch 2 (2-3s).

Figure 3B.

Means of ERD in all conditions





Examination of the grand average spectra revealed two prominent patches of 8-13Hz ERD across the scalp. Two symmetrical patches were selected on this basis, which represented the frontal cortex bilaterally, and are detailed in Figure 4a above. The ERD average computed for the repeated measures ANOVA was taken from these bilateral patches over the two separate time epochs of 1-2(s) and 2-3(s) post-stimulus.

The boxplots detailed in Figure 3B show that across all three conditions, male subjects showed stronger ERD than females in both time epochs, with the strongest ERD being in the second time epoch of 2-3(s) post-stimulus.

The data were approximately normally distributed, and examination of z scores revealed that the data were not significantly skewed or subject to kurtosis. A repeated measures 3×2×2

ANOVA was conducted, and the main results from the tests of within-subjects effects are detailed in Table 1 below.

Table 1 Within-Subjects Effects

Measure	Mean Square	F	df	P
Condition	1026.37	3.61	1.9	0.039
Condition*Gender	1203.51	4.23	1.9	0.024
Time*Gender	608.42	6.23	1	0.022

Greenhouse-Geisser corrected.

A Levene's test of homogeneity of variance was carried out and found to be non-significant. The main effect of condition was significant on the Greenhouse-Geisser ε correction $F(1.91, 36.3) = 3.60$, P= .039. Also, an interaction between gender and condition was significant on the Greenhouse-Geisser ε correction $F(1.91,36.3) = 4.23$, P= .024. Additionally, an interaction between time and gender was significant on the Greenhouse-Geisser ε correction $F(1,19) = 6.23$, P= .022. However, the tests of between-subjects effects showed that the main effect of gender was not significant $F(1,19) = .389$, P= .540. The interaction between gender and condition was explored further as it was considered more pertinent than the interaction between time and gender.

An interaction was found between gender and condition so a test of within subjects effects was conducted. Further exploration using a simple effects ANOVA, detailed in Table 2 below, showed that the effect of condition was significant in respect of females on the Greenhouse-Geisser ε correction $F(2,1.93) = 7.952$, $p= .004$. The analyses also showed that condition was not statistically significant in terms of the male subjects Greenhouse-Geisser ε correction $F(2,1.86) = 1.080$, $p = .356$. It can be concluded that the neutral, negative and positive conditions operated do not provoke statistically different responses in males, but do in the female subjects.

Table 2 Tests of Within Subjects Effects

Gender Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male Cond Greenhouse Geisser	173.740	1.864	93.219	1.080	.356
Female Cond Greenhouse Geisser	858.973	1.932	444.616	7.952	.004

The interaction plot detailed in Figure 4 below, illstrates that the interaction of female subjects and the negative condition 2 has the strongest impact on ERD. This implies that females respond most strongly to negative affective stimuli in comparison to positive affective and neutral stimuli. Male and female subjects exhibit a similar ERD means in terms of the negative condition, but show no similarity in the neutral condition, or positive condition. Males show a slight rise in ERD activity in respect of all three conditions which infers that they respond equally to all conditions irrespective of the emotional affect.

Figure 4 Interaction Plot detailing Gender × Condition

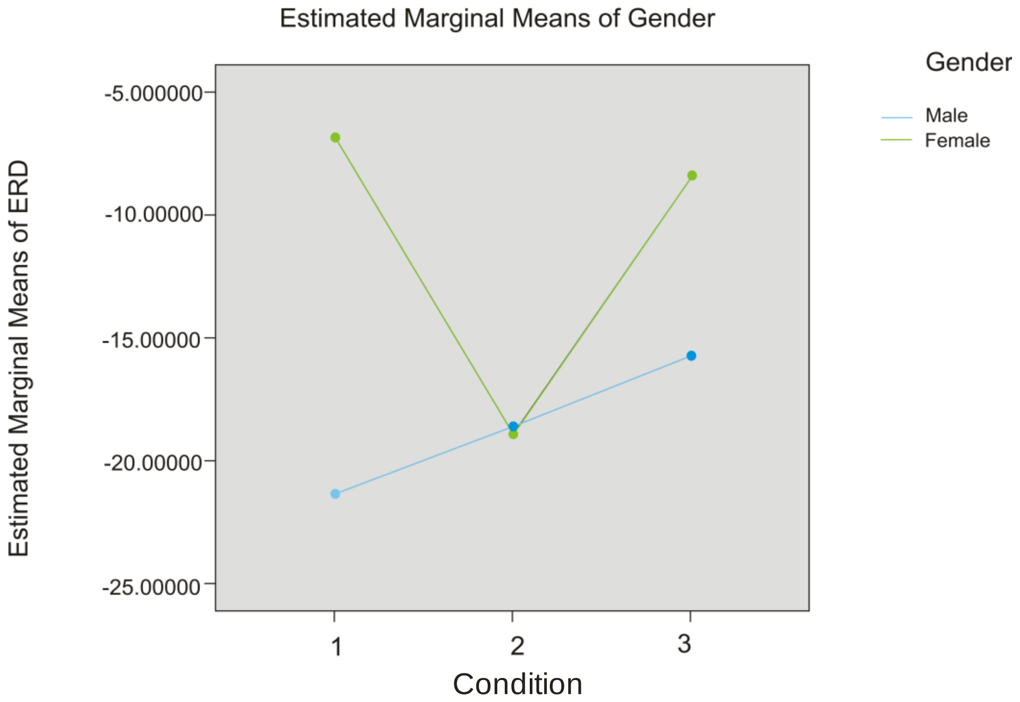


Table 3 Paired Samples T-Test for Gender × Condition effects.

Gender		Mean	Std. Deviation	t	df	Sig (2 tailed)
Male						
Pair 1	Neutral – Negative	-2.74158	13.67302	-.665	10	.521
Pair 2	Neutral –Positive	-5.61986	13.34688	-1.397	10	.193
Pair 3	Negative -Positive	-2.87829	10.85040	-.880	10	.400
Female						
Pair 1	Neutral – Negative	12.07405	10.05769	3.796	9	.004
Pair 2	Neutral –Positive	1.62013	11.31236	.453	9	.661
Pair 3	Negative -Positive	-10.45392	9.74300	-3.393	9	.008

A paired samples test was then conducted on both males and females to examine the individual differences of the conditions within the gender groups. The results in Table 3 show that none of the conditions yielded a significant result in terms of male subjects, with male subjects responding equally strongly to all conditions irrespective of valency. However, for females, the difference in respect of the neutral condition 1, versus the negative condition 2, was significant with an associated t-value of $t(9) = 3.80$, $p = .004$. Also, for females, the difference in respect of the negative condition 2, versus the positive condition 3, was significant with an associated t-value of $t(9) = 3.93$ $p = .008$.

Figure 5

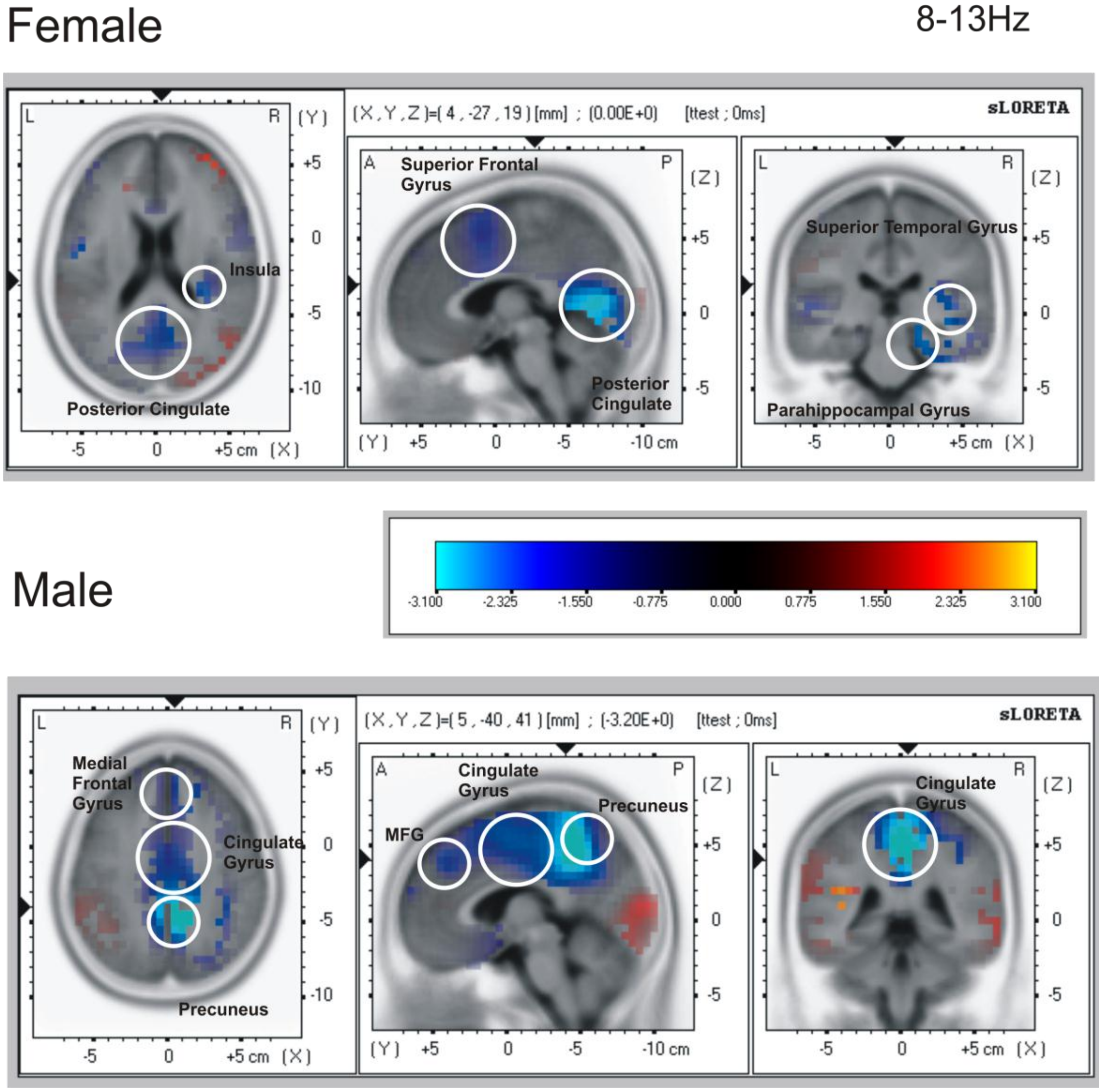


Figure 5 Loreta maps detailing the negative condition 2 for both a female and a male subject. For the female, the mapped t values taken 2.250(s) after stimulus onset showed that Brodmann's area 9, 13, 22, 28 and 30 are most activated. For the male, the mapped t values taken 1.625(s) after stimulus onset show Brodmann's area 6, 24 and 7 are the most activated. The image shows 3 orthogonal slices through the brain. Anatomy is represented in grey. LORETA values in blue indicate the strength of ERD. In the image, the left slice is axial (horizontal), viewing the head from the top. L=left, R=right. The center slice is saggital, viewed from the left. A=anterior, P=posterior. The right slice is coronal, viewed from the back. All axes and specified coordinates are in Talairach space. Black triangles along the axes indicate the point through which all three orthogonal slices are made. Its coordinates are indicated in the image as (x,y,z). The number in parenthesis, next to the coordinates, indicates the LORETA value of the selected point.

The LORETA maps were taken from the cortical ERD source in the negative condition for both genders. For the female example shown here, [x, y, z]=[4, -27, 19] (mm), the insula, the superior frontal gyrus , the superior temporal gyrus, and the parahippocampal gyrus were all activated in the Right Hemisphere. The posterior cingulate showed bilateral activation. For the male example shown here, [x, y, z]=[5, -40, 41] (mm), the medial frontal gyrus, the cingulate gyrus and the precuneus were all activated bilaterally.

Discussion

Gender and Condition

The results from the present study found that males on average show stronger ERD than females when viewing emotionally affective stimuli. Neutral, negative and positive conditions do not provoke statistically significant differences in the ERD of the male subjects, but statistically significant differences were found in the female subjects with regards to negative stimuli when compared to neutral and positive conditions. It can be concluded that males appeared to respond similarly to all the conditions operated here, where females responded more so to negative stimulus. However, both males and females showed similar ERD responses in terms of negative stimuli. It appears that an interaction of gender and condition; female and negative, has a significant outcome on the ERD response.

Gender and ERD

The topography of the 8-13Hz band is typically represented in the occipital, parietal and posterior temporal regions, with some activation shown in mid-temporal areas. The ERD grand average shown on the topographic maps here, illustrates that males show frontal, temporal, parietal and occipital symmetry in both time epochs and across all three conditions. The ERD appears stronger towards the left hemisphere, whilst the negative condition illicits the strongest occipital activation in the first time epoch. Frontal activation shown in this study appears consistent with a theory of attentional processes (Klimesch 1999). ERD was shown to be strongest for males in the positive condition which is consistent with the fMRI study of Wrase and colleagues (2003).

Females demonstrate very little ERD response in the frontal area; only mild activation in the cingulate cortex in the first time epoch when viewing positive stumuli. Instead, females employ pareito-occipital and occipital structures when evaluating emotionally salient stimuli. The occipital activation was represented bilaterally, consistent with Proverbio & Brignone (2006) and across both time epochs. Women showed greater activation in respect of negative stimulus, as found by Wrase et al (2003) which also found some activation of the cingulate cortex.

The areas of activation found in the present study in both males and females, have also been found by Jausovec & Jausovec (2008) and are highly implicated in a theory of neural efficiency. Both male and females subjects showed greater ERD activation in the second time epoch in both negative and positive conditions, but not in the neutral condition which may be consistent with ongoing appraisal (Canli, Desmond, Zhao, & Gabrieli 2002).

<u>LORETA</u>

Details from the LORETA maps show dominant RH activation for the female subject in respect of the negative condition at 2.250(s) post-stimulus. As the second epoch of the ERD was stronger than the first epoch, it may suggest ongoing appraisal of the stimulus. Should this be the case, then this finding may support the Right Hemisphere theory which purports that the function for emotional processing is lateralised in the RH with no hemisphere being responsible for processing different types of emotion (Ley & Bryden 1982). However, it also appears to support the valence theory of emotional processing which states that the RH processes negative emotions and the left hemisphere processes positive emotions (Davidson et al 1990). The data provided here in respect of females viewing negative affective stimuli, does not exclusively support either of the two major models of emotional processing.

The axial image shows the bilateral posterior cingulate is highly activated as well as the right insula. The posterior cingulate is implicated in the sensory input of emotions and receives many afferent axons from the thalamus, which is prolific in sensory processing. The ERD topographic maps show that the desychronisation appears to transform further to the posterior area during the second epoch, compared with more anterior in the first epoch. This may be indicative of a top-down processing phenomenon previously suggested by Onoda et al (2007). The insula, which is highly implicated in emotion, was also activated in the RH in the axial image. The insula has diverse functionality for emotional processing including perception, self-awareness, cognitive functioning and interpersonal experience. The implication of the insula here, demonstrates the female subject's use of diverse processes in attending to the stimulus.

The saggital slice shows the superior frontal gyrus (SFG) in the RH; an area implicated in self-awareness, and the posterior cingulate here is activated bilaterally. The coronal image illustrates that the superior temporal gyrus (STG) and the parahippocampal gyrus are both activated. The relationship between these areas and their effect on emotional processing is vital. The STG is instrumental in high level visual processing of complex stimuli such as faces, while the parahippocampal area focuses on the less complex aspects of visual processing. The parahippocampal area also plays an important part in memory encoding and retrieval. Overall, the LORETA maps show that females employ many cortical areas when viewing emotionally salient stimuli, predominantly in the RH. These areas are implicated in visual processing, cognitive functioning, memory encoding and retrieval, interpersonal experience and self-awareness. This illustrates that for females, many modalities are at work when engaging with emotionally affective standardized visual stimulus.

The LORETA map for the male subject showed that bilaterally, the medial frontal gyrus (MFG), the cingulate gyrus and the precuneus were all activated at 1.625(s) post-stimulus in the negative condition. This activation occurs up to, and the length of, the longitudinal cerebral fissure up into the parietal lobe. In this instance, both hemispheres are implicated in the process of attending to emotionally affective stimulus, which does not support a negative-positive dichotomy (Davidson et al 1990), or a RH theory (Ley & Bryden 1982). The sagittal image illustrates activation of the MFG in the RH, the cingulate gyrus and the precuneus. The cingulate gyrus co-ordinate the sensory input for emotions, and also the emotional response to pain. More importantly, both the MFG and the cingulate gyrus have been found to be part of a top-down attentional control network (Hopfinger, Buonocore & Mangun 2000). As this study demonstrated the ERD to be greater in the second epoch post-stimulus, it appears that this example, shown in the first epoch, highlights the structures employed and that these may well support a theory of top-down processing. The involvement of the precuneus demonstrates the use of functions such as episodic memory, visuo-spatial processing, and consciousness.

The data from the LORETA maps does not show convincing support for either the Valence or the RH model of emotional processing. What it does appear to illustrate, is that both males and females appear to engage in an ongoing evaluation of the stimulus, and that a process of top-down evaluation may occur. Another interesting observation, is that the cortical structures employed by men and women have been suggested in terms of a neural efficiency hypothesis (Jausovec & Jausovec 2008). Their study found that men appear more proficient than females in visuo-spatial tasks, and women more proficient than males at emotional processing. The cognitive aspect of visuo-spatial tasks implicates the precuneus, among other structures, and that was evidenced here. Whereas the female subject activated structures such as the insula which is highly implicated in emotional processing. It appears that the experimental paradigm has an effect on the outcome, as different studies elucidate different areas of activation. With respect, a generic model of emotional processing must be approached cautiously.

Implication of memory

Another area of interest in the present study is the activation of the parahippocampal area which is an important part of memory encoding and retrieval. Immediately present stimuli and stored representations are integrated into working memory (Baddeley 1986) by way of interactions among pre-frontal areas and sensory processing systems to the long term memory system in temporal areas. The involvement of working memory may involve interactions among several pre-frontal areas including the anterior cingulate, insula and orbital cortical regions, as well as dorso-lateral pre-frontal cortex (Lewis, Haviland-Jones & Barrett 2008). It has been suggested that a gender disparity exists as women encode emotional experiences in more detail than men (Seidlitz & Diener 1998), and the present study does show that women employ structures such as the insula and parahippocampal areas whereas men appear not to. Many of the regions associated with memory were activated during both time epochs post-stimulus, and thus it appears that memory and emotion are inextricably linked, and that memory does have an impact on how emotions are processed and perceived.

Behavioural data

The SAM ratings in respect of valency and arousal showed no significant gender differences in the present study. Therefore, both males and females reported the stimuli as equally arousing. However, there was a significant difference in females and their ERD response to the negative condition. A reason for this anomaly may be that stereotype behaviour expects women to be more emotionally expressive, and that women are aware of this stereotype when reporting subjective ratings, and therefore may not necessarily report subjectively (Plant, Hyde, Keltner, & Devine 2000). In essence, gender stereotypes can influence a subject's self-perceptions and thus their self-reports (Brody & Hall 2008). In addition, other research has found subjective ratings do not necessarily correlate with brain activation; as cortical differences have been found despite no recorded subjective gender differences (Kemp, Silberstein, Armstrong & Nathan 2003), (Canli, Desmond, Zhao & Gabrieli 2002). It appears that subjective ratings may be problematic as a benchmark for determining or examining neuroanatomical correlates of emotion. The data from the STAI in terms of state and trait anxiety also did not show any significant gender difference. Any observed differences in ERD responses or neuroanantomical correlates cannot be evaluated in terms of anxiety in the present study.

Future research

Other modalities have been implicated in the findings presented here, and their bearing on emotional processes must be explored further to examine gender differences. Splitting the 8-13Hz into lower and upper α band may have yielded differences between attentional systems in the frontal lobe and semantic processes in the parietal lobe that may have been of interest. An interesting observation of possible Event Related Potentials (ERP) appeared just at stimulus onset. Further exploration of this increase in activity could be perceived as inhibition, perhaps in respect of anticipatory response.

Conclusion

Men and women do employ different cortical structures when appraising emotionally salient stimuli presented in a standardised visual format. Men generally respond equally to emotionally salient images, but slightly more so to positive stimuli, whereas women have a far greater response to negative stimulus compared with neutral and positive stimulus. Also, strong ERD in the latter time period shows that males and females engage in ongoing appraisal of emotionally salient stimuli. The cortical areas activated also support a theory that top-down processes are employed by both men and women. The particular areas activated show an overlap with other modalities such as memory and visuo-spatial processing. The gender differences in cortical areas may well point to men and women engaging structures that are related to functions in which they are more proficient. Whilst there may be a body of research evidence to support either of the main theories of emotional processing, lateralisation is not the only feature. Several structures are employed during emotional processing and of these, differing structures used by males and females. It is these underlying modalities that can offer the greatest insight into how emotionally affective stimuli are processed, and ultimately why gender differences may occur in this phenomenon.

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