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Final dissertation

Gender effects in emotional picture processing:

An ERP study

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Table of contents

Abstract

Gender differences have always been a critical center of attention in psychological and psychophysiological research. Findings on this topic are especially important for the understanding of prevalence in psychological disorders, and could be used to create better treatment outcomes when factoring in these differences. In this experiment, 40 subjects (20 females) were selected from a previous larger sample, to participate a passive viewing task in which emotional images were presented on a computer screen and the 64-channel EEG was recorded. These images were divided in positive- and negative-valenced stimuli in order to investigate participants' physiological responses. Furthermore, they were asked to rate their valence and arousal to obtain a subjective evaluation by means of the Self-Assessment Manikin (SAM). This research was carried out to investigate possible gender differences on both psychophysiological data and subjective evaluations, with the purpose of shedding light on the ERP components that could highlight the differences between male and female brains (i.e., P1 and P300 components) and therefore finding out which one could be the more sensitive to the gender variable.

Chapter 1: Introduction

1.1 Gender and emotion definition

The issue of gender has been a critical focus of attention in the psychological research. Due to the subjective nature of this field, when dealing with patients, one of the many variables to take into account is their gender. As the American Psychological Association (APA) defines it, gender is *"[...] the condition of being male, female, or neuter, which implies the psychological, behavioral, social and cultural aspects of being male or female"* (American Psychological Association, APA, 2022). The difference in experience due to gender could be the key for a better understanding of the way the human brain works, depending on this variable, and could influence the way a patient with a certain psychological or psychiatric disease is treated. Furthermore, this kind of research can give a more in-depth view, explaining the meaning behind psychological diseases prevalence (in other words, why certain psychological diseases show a gender bias in their prevalence). In the field of psychophysiology, a specific research line has focused on the impact that gender effects on emotion processing and perception. Also, according to the APA (2022), emotion can be defined as *"[...] a complex reaction pattern involving experiential, behavioral and physiological elements, by which an individual attempts to deal with a personally significant matter or event"*. Every person experiences an array of emotions throughout lifetime, varying according to the situation the person is presented with. There have been many theories drawn trying to explain emotions, all with the goal of understanding the brain processing leading to a reaction when presented with a positive or negative stimulus. Three of the main theories are brought here to briefly explain how the emotion processing could work (Figure 1). The first one is the James-Lange Theory. This theory was presented separately by two psychologists, William James (1884) and Carl Lange (1885): their thoughts have been combined due to the similarities between them. What this theory states is that the awareness of the physical state of the individual leads to the identification of the subjective feeling (in other words, once the individual has recognized the state of arousal he/she is in, then he/she is able to give a name to the subjective feeling, thus identifying the emotion).

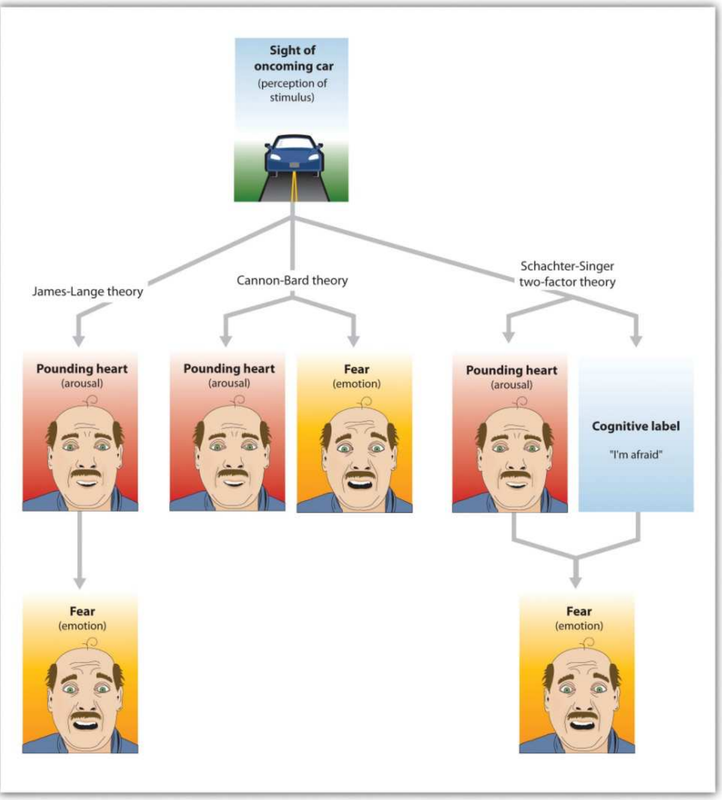


Figure 1: Representation of the theories of emotion.

The second theory is the Schachter-Singer two factor theory, developed in 1962, according to which a state of general arousal leads to the cognitive assessment of the context, which in turn leads to the identification of the emotion (this theory adds one step to the James-

Lange theory, suggesting that there is the need to contextualize a general arousal feeling to identify the emotion). The third theory is the Cannon-Bard theory, developed in 1927, according to which two separate processes are occurring simultaneously: the physical response and the recognition of the subjective feeling (Freberg, 2019, p. 521).

To give a meaning to the emotion felt, the valence of the emotion has to be considered. As defined by the APA (2022), emotional valence is *"[...] the value associated with a stimulus as expressed on a continuum from pleasant to unpleasant and from attractive to aversive"*. This definition is used to identify the emotion along two spectra, clarifying the nature of the feelings, and categorizing the reaction as positive or negative.

1.2. Neuroimaging discoveries of differences in emotional processing between genders

The question of the effects of gender differences in emotion perception led to many experiments which were trying to shed a light over this matter. In recent years, meta-analyses have started to be published, to summarize all the results found on this topic. Stevens and Hamann (2012) have collected studies carried out with functional Magnetic Resonance Imaging (fMRI), magnetic resonance imaging and Positron Emission Tomography (PET) with the intent of investigating the relation between these two variables. Overall, what was found is that, notwithstanding there is little evidence suggesting gender differences in affective responses to positive stimuli, limited evidence does exist pointing out that, when visualizing erotic stimuli, men are more emotionally aroused. A heavier focus has been on negative emotional stimuli, and, in general, women's reaction revealed higher values than those provided by men, possibly supporting the theory that these enhanced responses could contribute to the mechanisms that underlie the greater prevalence of depression and anxiety disorders in women (Stevens & Hamann, 2012, p. 1579). Notably, gender differences varied markedly as a function of negative and positive emotional valence: *"[...] the majority of sex differences favoring women were observed for negative emotion, whereas the majority of sex differences favoring men were observed for positive emotion*" (Stevens & Hamann, 2012, p. 1578). According to neuroimaging techniques, when presented with negative stimuli, a greater activation in women than men was found in the left amygdala; in addition, when the stimulus valence is not considered, greater activation was found in the anterior hippocampus and the left hippocampus. This finding is important to the psychological field due to the interaction of amygdala and hippocampus being known as one of the primary mechanisms through which emotion modulates episodic memory: this pattern suggests that there is an enhanced emotional memory in women when compared to their male counterpart. Furthermore, high levels of activation in women were also found in the anterior cingulate and medial prefrontal cortices, two regions that have been related to cognitive processes altered in depression (e.g., representation of mental states, default mode resting state activity and rumination). Of these processes, increased rumination (defined by the APA, 2022) as *"[...] obsessive thinking involving excessive, repetitive thoughts or themes that interfere with other forms of mental activity"*) has been linked to the higher prevalence of depression in women (Stevens & Hamann, 2012). On the other hand, men exhibited greater activation when presented with positive stimuli in the left amygdala (it is worth noting that positive stimuli here do not only include those belonging to the erotic category, but in general those stimuli that can create a general feeling of positive arousal). This greater activation is also overlapped to entorhinal cortex, a region of the medial temporal lobe playing an important role in episodic memory, especially supporting successful encoding and retrieval of declarative memory (Stevens & Hamann, 2012). Five years later, a study by Filkowski et al. (2017) was published, with the purpose of solely identify neural gender differences. This meta-analysis used results from 56 studies with emotion-eliciting stimuli. These findings are confirming those reported above, and analyzed more in depth the brain regions involved. Five brain areas showed a greater activation in male participants: the mediodorsal nucleus of thalamus (MDN), bilateral pulvinar, frontal pole and a cluster including anterior cingulate cortex (ACC) and right medial prefrontal cortex (mPFC). In contrast, female participants showed higher levels of activation in the bilateral amygdala, left hippocampus and regions of dorsal midbrain including periacqueductal gray/superior colliculus and locus coeruleus (Filkowski, Olsen, Duda, Wagner, & Sabatelli, 2017). The pattern of differences found is consistent with the perspective stating that men engage the frontal cortical regions in volitional control processes during emotional cues (which could be explaining the reduced amygdala activity). Women, on the other hand, show enhanced subcortical sensitivity to emotional cues, consistent with the evolutionary bias towards harm avoidance (Filkowski, Olsen, Duda, Wagner, & Sabatelli, 2017).

1.3 The use of ERPs in emotional processing

Although fMRI and other neuroimaging techniques have given researchers a really in-depth view of the brain regions involved in emotional processing, there is something lacking with this approach. As Ding et al. (2017) explain, there are some flaws when using just fMRI. This method has a great spatial resolution, but has a lower temporal resolution than others. This is where ERPs come into play (Ding, Li, Wang, & Luo, 2017). First off, ERPs is the abbreviation for "event-related potentials", defined by the APA (2022) as *"[...] a specific pattern of electrical activity produced in the brain when a person is engaged in a cognitive act"*. There are several different ERP components, and most of them have been associated, through the amplitude or latency, with a specific cognitive process. Despite a lower spatial resolution, the ERP technique allows the assessment of emotion processing with a millisecond temporal resolution, providing a great way to investigate the temporal dynamics of emotion processing (Ding, Li, Wang, & Luo, 2017). Research using ERPs to investigate emotion has discovered many ERP components that can be linked to the processing of emotional stimuli, such as the N100, P100, N170, vertex positive potentials (VPP), N250, N300, P300, late positive potentials (LPP) and early posterior negativity (Ding, Li, Wang, & Luo, 2017). In particular, the N170 is the electrophysiological index of face processing, as past studies revealed that it is sensitive to facial expressions displaying anger, happiness and fear (Hinojosa, Mercado, & Carretié, 2015). The P300 was instead used to investigate sex-related hemispheric lateralization of electrical potentials when being exposed to the emotional content of a story. The emotional stimuli elicited a stronger P300 in women, compared to men, in the left hemisphere, whereas a stronger P300 was found in the right hemisphere in men than in women (Gasbarri, et al., 2006). Furthermore, it was found that females responded with enhanced negative components (N100 and N200) in comparison to males when viewing unpleasant visual stimuli and emotional arousing stimuli (Lithari, et al., 2009).

In the present study, the research focused on the P1 component, defined as *“[…] the first positive component of an event-related potential, occurring approximately 100 ms after stimulus onset*” (APA, 2022) and the P300 component, *“[…] the third positive component of an event-related potential, which appears approximately 300 ms after stimulus onset”* (APA, 2022), in order to find which one could be more sensitive to gender effect during the emotional processing.

Chapter 2: The research

The study of emotion, as previously said, is a key topic in the psychophysiological field. As gender is one of the main variables to take into account when conducting an experimental research, it is important to give it the right importance. Research on the differences in emotional responses between males and females not only shed a light on how differently the brain can work due to this key difference, but could also help to clarify both the role of emotion in everyday life according to it, and how individuals could be predisposed to certain mental conditions that act as key factors underlying psychological and/or psychiatric diseases. There has been various evidence in this field, obtained using different techniques applied to gender-emotion investigation. Our decision to use the ERP method depends on the purpose to study the temporal dynamics associated to emotion reactions, focusing in particular on the automatic, early steps of emotional stimulus processing. Furthermore, the use of visual stimuli of different nature gives a wide perspective of analysis, moving along the emotional spectrum, and providing a method of comparison between findings in the same study.

2.1 Participants

A preliminary online questionnaire was completed by a sample of 215 young and healthy adults. This online screening included questions about age, educational levels, neurological or psychiatric disorders, use of drugs, as well as an empathy and a fear inventory. In particular, only heterosexual participants were enrolled in the study, due to the content of our erotic emotional stimuli, which were characterized by the presence of heterosexual couples only. We then excluded participants with specific phobias (e.g., phobia for firearms, knives, blood) and/or with neurological or psychiatric disorders. The final sample was thus composed by 40 participants (20 women, mean age: 22.45 ± 2.91 years; 20 men, mean age: 22.40 ± 2.41 years; t(38) = 1.24, n.s.) with normal or corrected-to-normal vision. All participants were more than 18 years old, and gave their written informed consent to take part in the experiment, according to the Declaration of Helsinki. The experimental procedure was approved by the Psychology Ethics Committee of the University of Padova (Protocol n. 4440).

2.2 Procedure and Stimuli

Before the experiment was carried out, each participant completed two questionnaires: the STAI and the PANAS questionnaires. The State-Trait Anxiety Inventory (STAI Y1 and Y2) is a test aiming at measuring trait and state anxiety. Trait anxiety is defined as *"[...] the proneness to experience anxiety"*, meaning that people who score high on this variable tend to view the word as more dangerous or threatening (APA, 2022). State anxiety, on the other hand, can be defined as *"[...] anxiety in response to a specific situation that is perceived as threatening or dangerous"* (APA, 2022). Due to the nature of the stimuli that have been presented to the participants, this gives the researcher a tool to better analyze the response that is seen in the single subject and helps to contextualize it. This questionnaire has 20 items for each anxiety category, which are rated on a 4-point scale. The Positive and Negative Affect Schedule (PANAS) on the other hand, is a self-report instrument aiming at assessing the internal feeling state during a time period specified by the researcher. It is made out of two subscales, each having 10 items. The Positive Affect (PA) Scale reflects the level of pleasant engagement, or the extent to which a person feels enthusiastic, excited, active and determined (APA, 2022). The Negative Affect (NA) Scale reflects the level of unpleasant engagement and subjective distress, and it takes into account a broad range of negative affects, including fear, nervousness, guilt and shame (APA, 2022). After taking these two tests, the researcher collected EEG for 5 minutes, in a condition termed open-eyes resting state, meaning the EEG of an individual which is not subjected to any task in that particular period of time. Then, the emotional task took place while EEG was recorded. Each stimulus was presented for 2 seconds, after which a black screen was presented to separate between the different stimuli. After this passive viewing task, participants were asked to rate both pleasantness and activation via a Self-Assessment Manikin (SAM) questionnaire (Bradley & Lang, 1994). The valence and arousal judgment scale ranged from 1 (low) to 9 (high). EEG data were collected during the passive viewing task using a standard 64-channels cap (Acticap, BrainProduct System). During the collection of EEG signal, each subject was asked to look at the computer screen where the images were presented. Every image administered is part of the International Affective Picture System (IAPS) (Lang & Cuthbert, 1997). This database comprises a series of visual stimuli which are of emotional nature, normative and internationally available. It is one of the most reliable sources used in experimental emotional research (Jayaro, de la Vega, Díaz-Marsá, Montes, & Carrasco, 2008). Five kinds of stimuli were shown: two negative-valenced stimuli, two positive-valenced stimuli and one neutral condition stimuli. The two negative-valenced stimuli belonged to two categories: fear (usually an image of something scary, such as a snake) and mutilation. On the other hand, the two positive-valenced stimuli were either belonging to the erotic category or the extreme sports category. A neutral stimulus category was also used, consisting in images of ordinary objects (such as a cup) that should not lead to any major emotional response.

2.3 EEG preprocessing

A major step before the data analysis is carried out is the preprocessing. In order to complete this process, two software have been used. The BrainVision Analyzer (Brain Products GmbH, Germany) was used after the EEG data recording collection, to visualize the electrodes and decide whether any of these channels needed to be interpolated due to noise. The process of interpolation can be explained, in basic terms, as *"[...] determining an unknown value given knowledge of the surrounding data points"* (APA, 2022). The channels near the selected one were used to estimate the activity of the bad one. The method used was the triangulation and linear interpolation method.

EEG was recorded in DC mode and the activity of each electrode was online referred to FCz. The sampling rate was set at 1000 Hz, and the impedance was kept below 5 kΩ throughout the recording. The activity of FCz was reconstructed and data were off-line re-referenced to the average reference. After this step is completed, the new set of data can be moved to Brainstorm (Tadel, Baillet, Mosher, Pantazis, & Leahy, 2011). A MatLab script was used to carry out the preprocessing steps, including the import of the correct file into the software, the import of the channel file and the application of a band-pass filter. This filter is used to attenuate frequencies higher and lower than the cutoff frequency. In this case, the lower cutoff frequency was 0.5 Hertz (Hz), whereas the upper cutoff frequency was 125 Hz. Once this process was finalized, the Independent Component Analysis (ICA) was implemented. This process is a computational method used to separate a signal into its subcomponents. This is done to verify that no noise, especially due to eye movements, is present in the recording. For this set of participants, two noises were generally identified: a blink noise, with a characteristic high amplitude that appears in most of the channels for a brief period of time, and a horizontal eye movement noise. Once the selection was completed, the epoch time was set for all stimuli and subjects, to compare them with one another: the epoch time chosen ranged between -500 and 2000 milliseconds (ms) before and after the stimulus onset, respectively. This created a Brainstorm subfolder for each stimulus, including 26 epochs for each kind of stimuli (i.e., erotic, sport, mutilation, fear pictures). The baseline correction (-100/0 ms) was thus computed on each epoch. Epochs with residual noise were deleted first by using a peak-to-peak procedure (threshold value = ± 100 microVolts, μV) that rejected the entire epoch, and lastly by visually inspecting the residual artifact-free epochs.

2.4 Behavioral statistical analysis

In order to investigate the behavioral measures involved in this experiment, the repeated measures of ANOVA statistic was used. The acronym ANOVA stands for "analysis of variance", and it can be defined as *"[...] a statistical method studying variation in responses of two or more groups on a dependent variable"* (APA, 2022). As previously stated, participants had to rate the images along two spectra: valence and arousal. Two separated ANOVA were thus computed for analyzing valence and arousal judgments (2 gender [males *vs.* females] x 5 stimuli [sport *vs.* erotic *vs.* neutral *vs.* mutilation *vs.* fear]). Data analyses were performed using the Statistica 6.1(StatSoft GmbH) software. Post-hoc comparisons were computed using the Newman-Keuls method ($p < 0.05$), and the Greenhouse-Geisser correction was applied when necessary (i.e., for df > 2).

2.5 ERP analysis

P1 and P300 components were analyzed. The time window of the P1 component corresponded to the 110-130 ms temporal interval after stimulus onset. The P300 component included the 200-340 ms interval after stimulus onset. Two clusters of electrodes were created including 5 parieto-occipital sites in left hemisphere (P7-P5-PO7-PO3-O1) and 5 parieto-occipital electrodes in the right hemisphere (P8-P6-PO8-PO4-O2). ERPs data was thus analyzed by means of ANOVA (2 gender [males *vs.* females] x 5 stimuli [sport *vs.* erotic *vs.* neutral *vs.* mutilation *vs.* fear] x 2 laterality [left *vs.* right]).

2.6 EEG Source Localization

Localization of the neural sources underlying the effects of the emotional stimulation in male and female groups was computed using the standardized low resolution brain electromagnetic tomography (sLORETA) method (Pascual-Marqui, Esslen, Kochi, & Lehmann, 2002). Since sLORETA computes the smoothest possible 3D-distributed current source density solution constrained to grey matter, this approach was particularly suited for our analysis since, due to the smoothness constraint, it does not need an *a priori* definition of known sources. Separate t-tests (5000 permutations) were carried out for (a) between-group analysis, regardless of stimulus content, on each component (i.e., P1, in the 110-130 ms interval, and P300, in the 240-300 ms interval after stimulus onset); (b) by comparing, for each group and stimulus, the electrical activity within the P1 interval (110–130 ms after stimulus onset) with that of an interval with no active linguistic processing (the 20-ms baseline prior to stimulus onset), and within the P300 interval (200–340 ms) with an equivalent neutral interval (i.e., the 140-ms baseline). All results are expressed in Talairach coordinates.

2.7 Results

2.7.1 Valence and Arousal

The ANOVA (2 gender [males *vs.* females] x 5 stimuli [sport *vs.* erotic *vs.* neutral *vs.* mutilation *vs.* fear]) on the valence ratings revealed a gender main effect ($F_{1,\ 38} = 6.25$, $p = 0.017$), with overall males ratings being higher than those of women, when considering the five stimulus category together (M = 4.58, F = 4.10, respectively). A stimulus main effect was significant too ($F_{4,\ 152} = 225.77$, HF $\varepsilon = 0.78$, $p < 0.001$), showing that there were significant differences between the contents of images presented, in line with the inclusion of those images in the category of positive/negative stimuli. Furthermore, the 2-way gender by stimulus interaction was statistically significant ($F_{4,\ 152} = 3.57$, HF $\varepsilon = 0.78$, $p = 0.01$). As shown in Figure 2, there is a significant difference between males’ and females’ ratings for erotic images ($p < 0.001$) and for fear images ($p < 0.05$); coherently with the gender main effect, males rated both kinds of images higher than females.

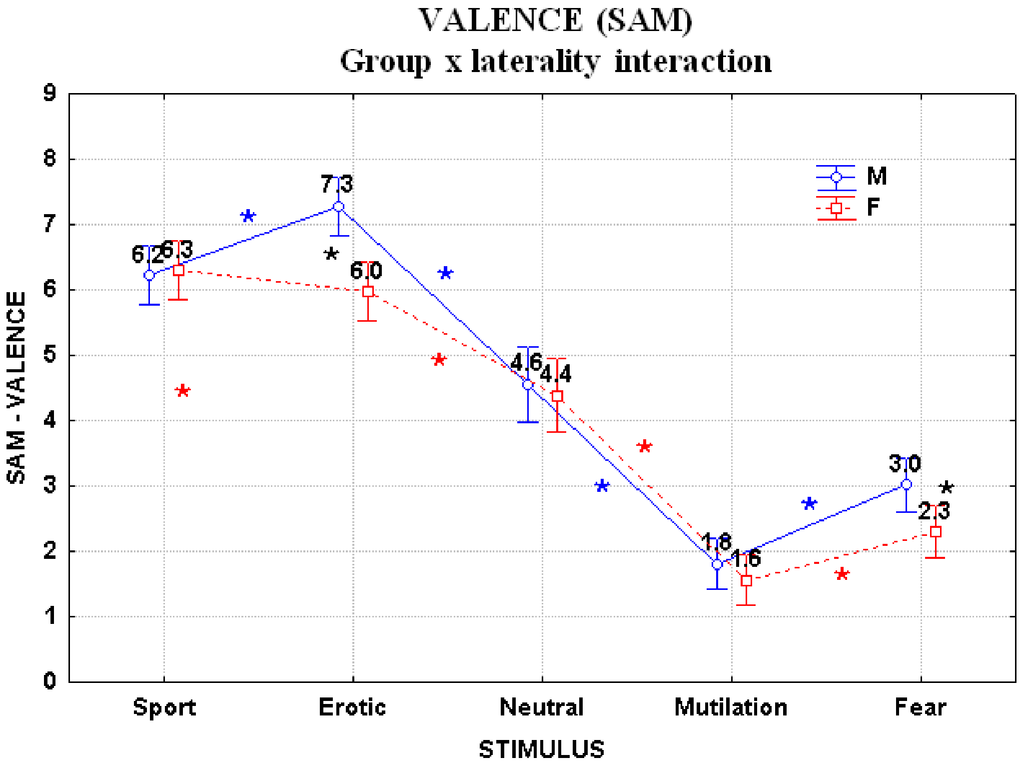


Figure 2: Gender x stimulus interaction for valence (SAM).

It is also important to report the differences within gender in the images rating. For males, as reported in Figure 2, differences can be found in sport *vs.* erotic ($p < 0.001$), erotic *vs.* neutral ($p < 0.001$), neutral *vs.* mutilation ($p < 0.001$) and fear *vs.* mutilation ($p < 0.001$). For females, differences can be found in erotic *vs.* neutral ($p < 0.001$), neutral *vs.* mutilation ($p < 0.001$) and fear *vs.* mutilation ($p < 0.05$). Similar results were obtained when analyzing results collected from the arousal scores, although here a gender main effect is not present. A stimulus main effect can still be found ($F_{4, 152} = 101.63$, HF $\varepsilon = 0.84$, $p < 0.001$), together with the 2-way gender by stimulus interaction effect ($F_{4, 152} = 5.71$, HF $\varepsilon = 0.84$, $p < 0.001$). As shown in Figure 3, differences between gender scores can be found, as for valence ratings, in the erotic category ($p < 0.05$), with males ratings showing higher evaluations than females; for the mutilation category, however, females ratings were higher than males' scores (p < 0.001), unlike valence results.

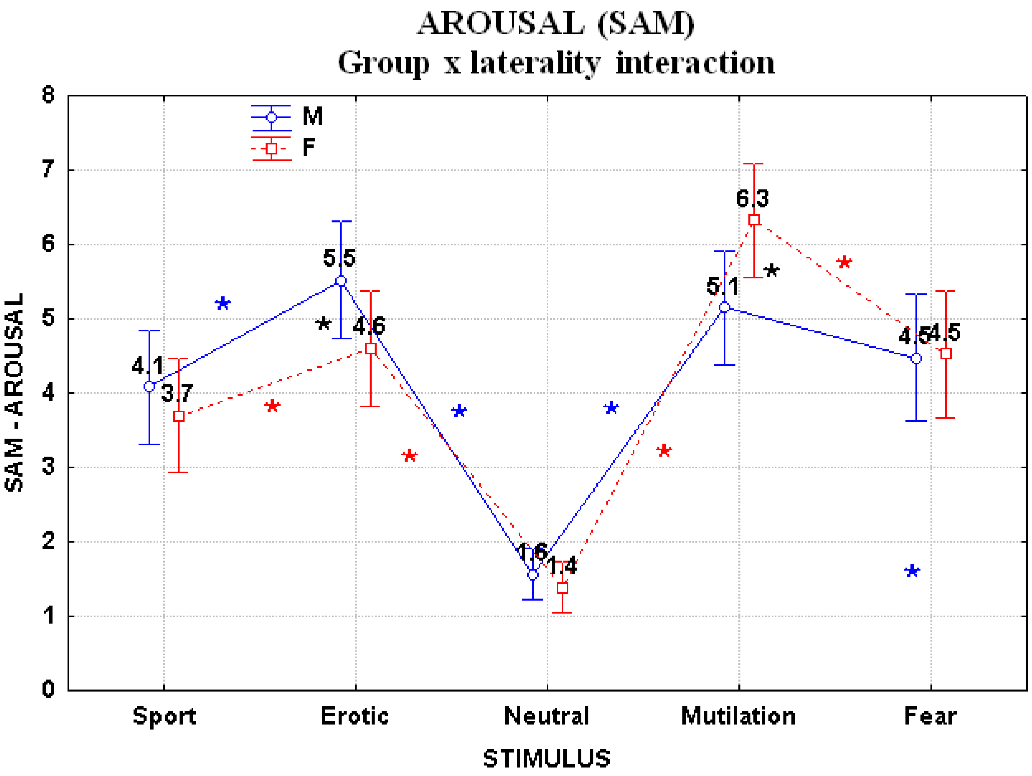


Figure 3: Gender x stimulus interaction for arousal (SAM).

As for differences within gender, also reported in Figure 3, for males they can be found in the erotic *vs.* sport (p < 0.001), erotic *vs.* neutral (p < 0.001) and mutilation *vs.* neutral (p < 0.001), whereas for females, differences can be found in the erotic *vs.* sport (p < 0.05), erotic *vs.* neutral (p < 0.001), mutilation *vs.* neutral (p < 0.001) and mutilation *vs.* fear (p < 0.001).

2.7.2 ERP analysis: P1 component

As above-mentioned, for the analysis of the ERP data, the first component taken into consideration was the P1, occurring approximately 110-130 ms after stimulus onset. The clusters of electrodes selected to investigate the P1 amplitude component were selected according to the maximum peaks seen in the brain waves analysis. As the P1 is an early component, peaks were the most prominent in the parieto-occipital region of the brain, including P7-P5-PO7-PO3-O1 and P8-P6-PO8-PO4-O2 in left and right hemisphere, respectively. An ANOVA with repeated measures (2 gender [males *vs.* females] x 5 stimuli [sport *vs.* erotic *vs.* neutral *vs.* mutilation *vs.* fear] x 2 laterality [right *vs.* left]) was carried out. A stimulus main effect ($F_{4,152}$ = 4.20, HF ε = 0.95, p = 0.002] was found: significant differences emerged between both erotic and mutilation *vs.* neutral (p = 0.04 and p = 0.03, respectively), with emotional stimuli eliciting greater P1 amplitude (measured in µV) than neutral images (Figure 4).

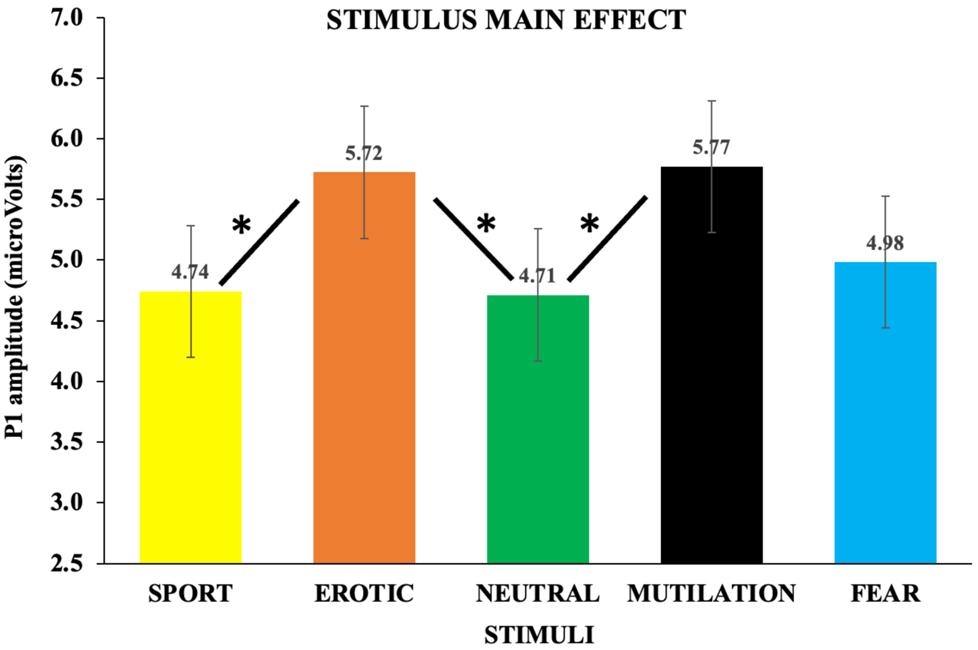


Figure 4: Stimulus main effect for the P1 component.

In addition, erotic pictures showed grater P1 amplitudes compared with Sport stimuli (p = 0.05). To summarize, the P1 amplitude reached the maximum amplitude when associated with mutilation and erotic stimulus processing, the neutral and sport categories had the lowest activation, and there was no significant difference between all stimuli and fear stimuli.

Notably, results also showed a 2-way significant interaction between group and laterality ($F_{1,\ 38}$ = 7.44, p = 0.001], revealing that the P1 amplitude in the right hemisphere was significantly higher for females than males (p = 0.002; Figure 5). In addition, for females only, greater P1 amplitude was found in the right *vs.* left cluster (p = 0.019). No differences emerged for the male group between left and right hemisphere.

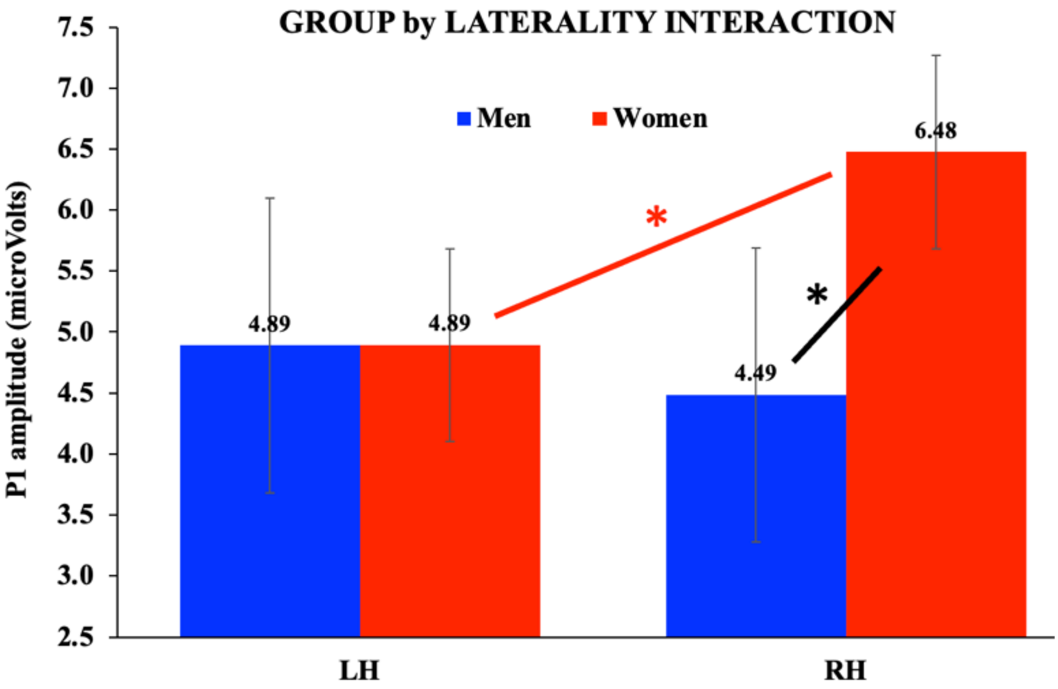


Figure 5: Gender x hemisphere interaction for the P1 component.

2.7.3 Source analysis on P1 components

The source analysis carried out on the P1 component including all stimuli between females and males (thus following the ERP results) showed a significant greater activation in women *vs.* men (t = 1.27, p < 0.001) in MNI coordinates X = 5, Y = -80, Z = 10, corresponding to the right cuneus (Brodmann area, BA, 17) (Figure 6).

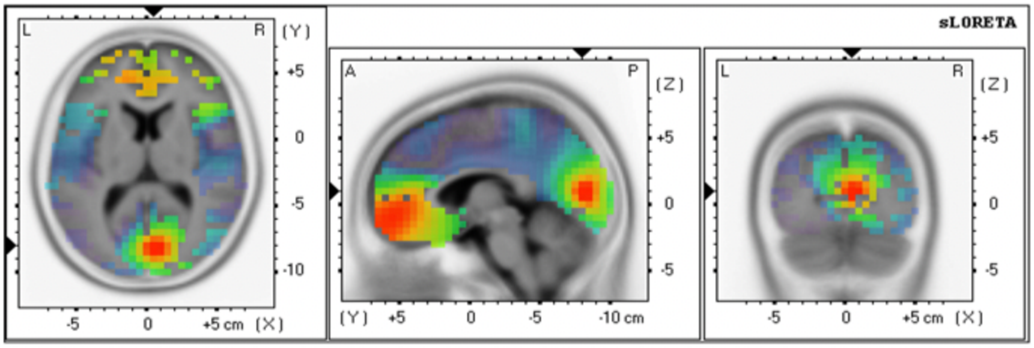


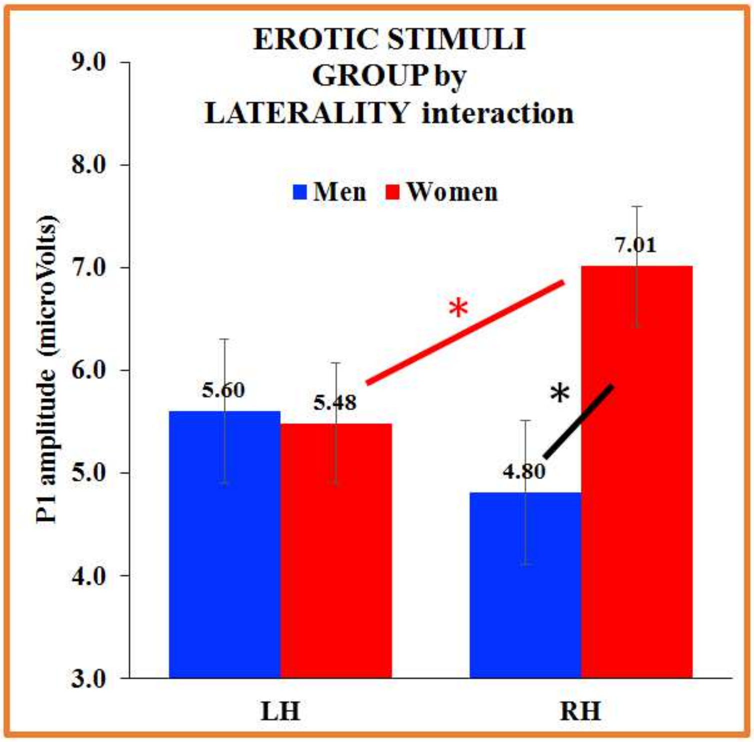
Figure 6: P1 source analysis (sLORETA) revealed greater females' activation in the right cuneus.

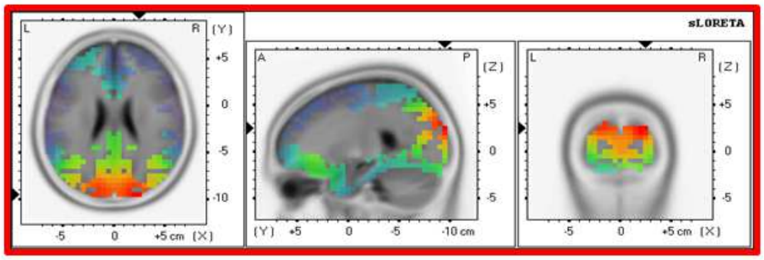
2.7.4 Separate ANOVAs and Source analysis on emotional stimuli (P1 component)

Given the main effect of the stimulus observed before, together with the 2-way group by laterality interaction, separate ANOVAs were conducted for each emotional stimulus, in order to carry out a more fine-grained analysis aimed at reveal which stimuli were the most responsible for gender differences.

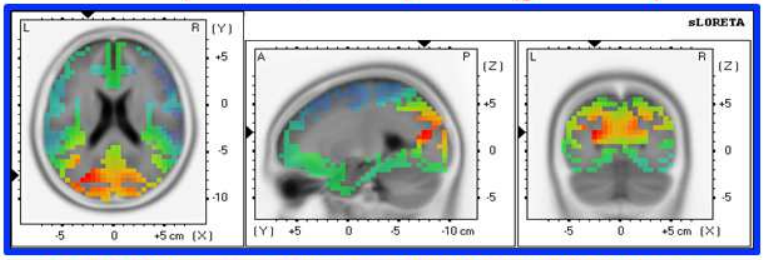
The only case in which there was no significant P1 results was for the sport category. For the erotic stimuli category, the 2-way interaction group x laterality was found ($F_{1, 38} = 6.92$, p = 0.01): as can be seen in Figure 7 (top panel, in orange), females showed greater P1 amplitude in the right *vs.* left cluster (p = 0.048), but also greater amplitude than males in the right hemisphere cluster (p = 0.006). No laterality effect was found for the male group.

As the between group sLORETA analysis carried out on the P1 showed no significant gender differences, we carried out separate analyses on females and males P1 generators. These latter analyses revealed a neural generator in the right cuneus (BA 19, MNI X = 25, Y = -95, Z = 25; t = 3.97, p < 0.001) for females, and in the left cuneus (BA 18, MNI X = -25, Y = - 75, Z = 20; t = 3.66, p < 0.001) for males.





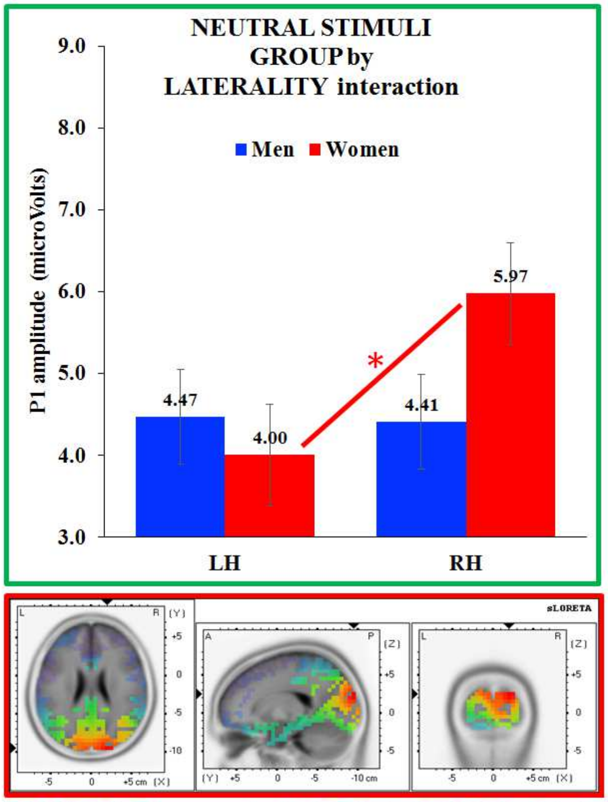
WOMEN's P1 source in the RIGHT CUNEUS (BA 19)
MNI X= 25 , Y= -95 , Z= 25 [t = 3.97, p < 0.001]



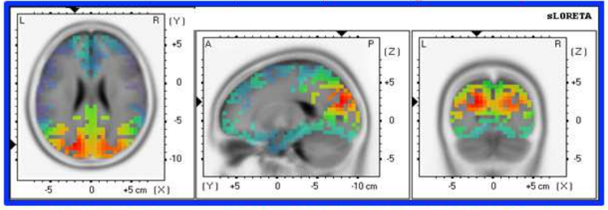
MEN's P1 source in the LEFT CUNEUS (BA 18)
MNI X= -25 , Y= -75 , Z= 20 [t = 3.66, p < 0.001]

Figure 7: Gender x laterality interaction for the P1 component on erotic stimuli (top panel, in orange) and source analysis on P1 generators separate for women (bottom panel, in red) and men (bottom panel, in blue).

Thus, the P1 generator appeared located in the cuneus in both groups, with an opposite hemisphere engagement for women (right side) and men (left side) (Figure 7, bottom panels in red and blue color, respectively). For the neutral category, the 2-way interaction group x laterality was also observed ($F_{1, 38} = 7.812$, $p = 0.008$): whilst no laterality effect was found in males, in females there was greater P1 amplitude in the right vs. left cluster ($p = 0.002$), but no significant between-group differences were found (top panel of Figure 8, in green).



WOMEN's P1 source in the RIGHT CUNEUS (BA 19)
MNI X= 20 , Y= -95 , Z= 25 [$t = 3.59, p < 0.001$]



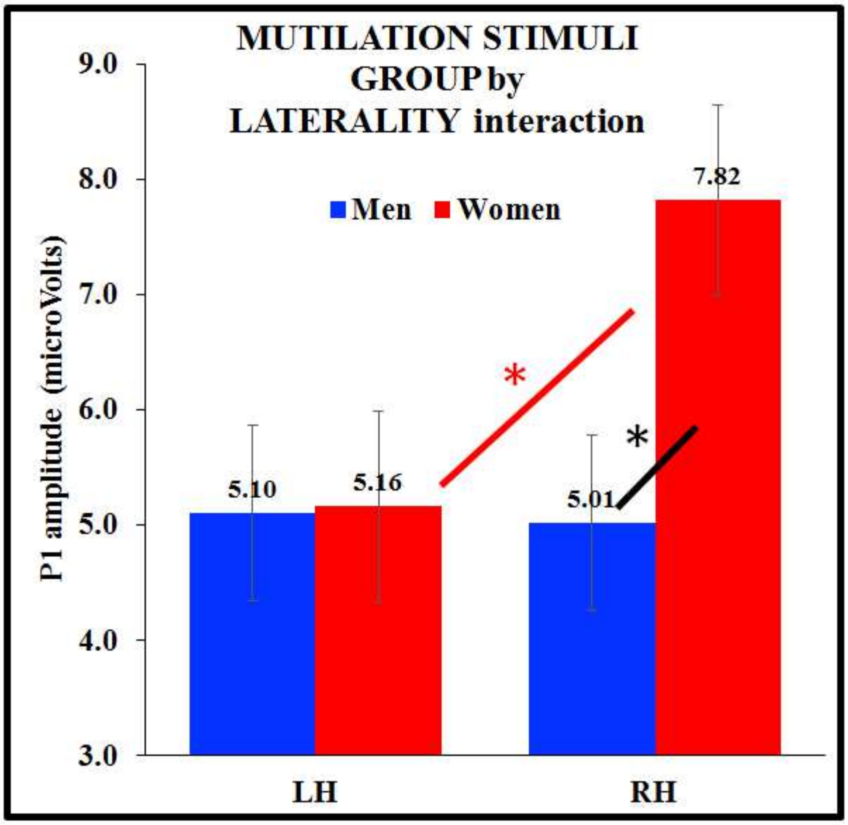
MEN's P1 source in the LEFT CUNEUS (BA 18)
MNI X= -20 , Y= -80 , Z= 25 [$t = 3.29, p < 0.001$]

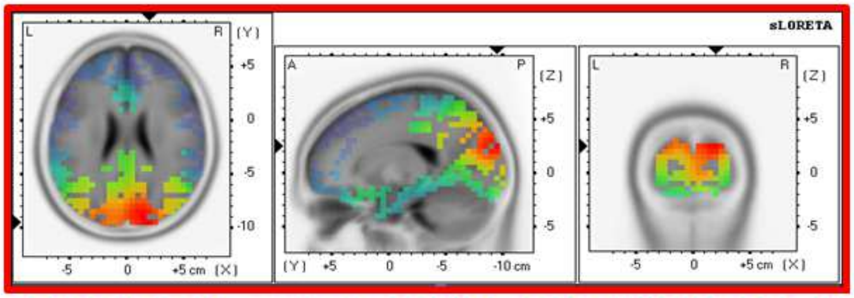
Figure 8: Gender x laterality interaction for the P1 component on neutral stimuli (top panel, in green) and source analysis on P1 generators separate for women (bottom panel, in red) and men (bottom panel, in blue).

As the between group sLORETA analysis carried out on the P1 showed no significant gender differences, we carried out separate analyses on females and males P1 generators. These latter analyses revealed a neural generator in the right cuneus for females (BA 19, MNI X = 20, Y = -95, Z = 25; $t = 3.59$, $p < 0.001$), and in the left cuneus for males (BA 18, MNI X = -20, Y = -80, Z = 25; $t = 3.29$, $p < 0.001$). Thus, as for the erotic images, the P1 generator appeared located in the cuneus in both groups, with an opposite hemisphere engagement for women (right side) and men (left side) (Figure 8, bottom panels in red and blue color, respectively).

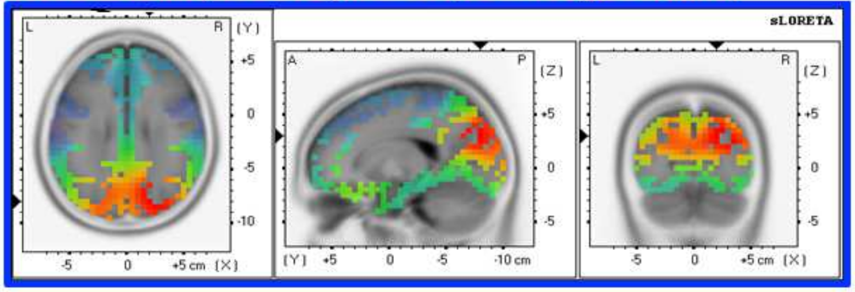
Moving onto the negative categories, for the mutilation stimuli there was a significant 2-way group x laterality interaction, shown in Figure 9 (top panel in black ; $F_{1, 38} = 7.29$, $p = 0.01$): a laterality effect was observed in females, who exhibited greater P1 amplitude in the right *vs.* left cluster ($p = 0.004$), and also a greater amplitude than males in the right cluster ($p = 0.002$).

As the between group sLORETA analysis carried out on the P1 showed no significant gender differences, we carried out separate analyses on females and males P1 generators. These latter analyses revealed a neural generator in the right cuneus for both females and males (BA 19, MNI X = 20, Y = -95, Z = 25; $t = 4.24$, $p < 0.001$; and BA 19, MNI X = 20, Y = -80, Z = 30; $t = 3.37$, $p < 0.001$, respectively). Therefore, unlike erotic and neutral images, mutilation images activated the right cuneus in both groups, thus revealed that this kind of emotional contents is not affected by gender bias (Figure 9, bottom panels in red and blue color, respectively).





WOMEN's P1 source in the RIGHT CUNEUS (BA 19)
MNI X= 20 , Y= -95 , Z= 25 [$t = 4.24, p < 0.001$]



MEN's P1 source in the RIGHT CUNEUS (BA 19)
MNI X= 20 , Y= -80 , Z= 30 [$t = 3.37, p < 0.001$]

Figure 9: Gender x laterality interaction for the P1 component on mutilation stimuli (top panel, in black) and source analysis on P1 generators separate for women (bottom panel, in red) and men (bottom panel, in blue).

Lastly, for the fear category, the significant 2-way group x laterality interaction was observed ($F_{1, 38} = 4.28$, $p = 0.045$): a gender effect appeared in the right cluster, females showing greater P1 amplitudes than males (top panel in Figure 10, in sky).

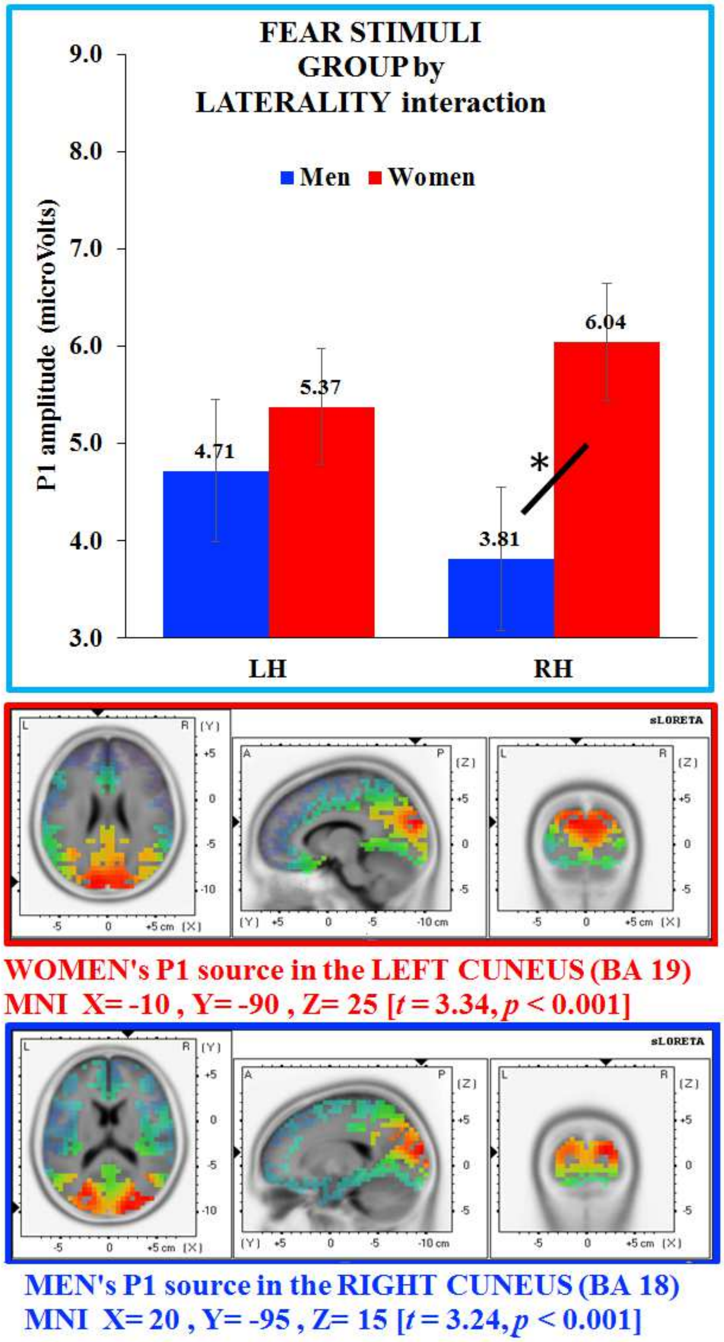


Figure 10: Gender x laterality interaction for the P1 component on fear stimuli (top panel, in sky) and source analysis on P1 generators separate for women (bottom panel, in red) and men (bottom panel, in blue).

As the between group sLORETA analysis carried out on the P1 showed no significant gender differences, we carried out separate analyses on females and males P1 generators. These latter analyses detected a neural generator in the left cuneus (BA 19, MNI X = -10, Y = -90, Z = 25; t = 3.34, $p < 0.001$) for females, and in the right cuneus for males (BA 18, MNI X = 20, Y = -95, Z = 15; t = 3.24, $p < 0.001$). Thus, the P1 generator appeared located in the cuneus in both groups, with an opposite hemisphere engagement for women (left side) and men (right side) (Figure 10, bottom panels in red and blue color, respectively).

2.7.5 ERP analysis: P300 component

The second important key component in the analysis of ERP data associated with emotional processing was the P300 component, occurring approximately 200 to 340 ms after the stimulus onset, as previously stated. The cluster of electrodes used for the statistical analysis was the same described for the P1 component. The ANOVA revealed a stimulus main effect ([$F_{4,\,152} = 43.76$, HF $\varepsilon = 0.98$, $p < 0.001$): significant differences were found for sport and erotic images *vs.* all the other stimuli (all ps < 0.001; Figure 11).

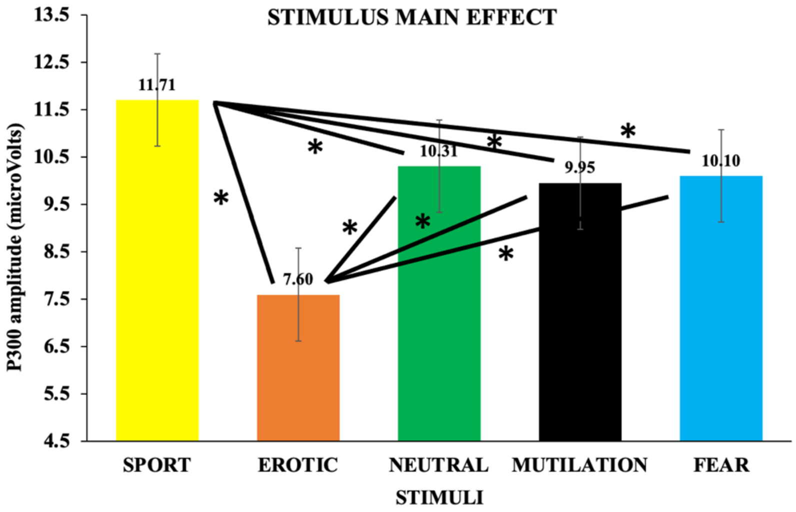


Figure 11: Stimulus main effect for the P300 component.

Therefore, regardless of gender, the greater P300 amplitude was measured in response to sport stimuli, whereas the lowest amplitude was measured in response to erotic stimuli (see Figure 11). No significant differences were found when comparing the amplitudes of neutral, mutilation and fear stimuli. Furthermore, a laterality main effect was found ($F_{1, 38} = 12.59$, $p = 0.001$). The right cluster showed greater P300 amplitude (mean = 10.45 ± 1.57 μV) than the left one (mean = 9.42 ±1.48 μV).

Chapter 3: Discussion and final remarks

The goal of this research was to investigate the physiological responses to visual emotional stimuli to determine whether the gender variable had any effects on the results found. To ensure that the differences found could be attributed just to the gender variable, all other variables in the participants' sample were controlled, including age, education level, possible psychological and psychiatric disorders, drug abuse, as well as the empathy level, which could have caused some results to shift according to the single participant's level (some could be more sensitive to certain emotional stimuli, causing a noise in the overall results).

3.1 Discussion of behavioral results

In this study, the main findings regarding the stimulus valence consisted in the fact that, compared with females, males rated as more pleasant both fear and erotic stimuli. These results are supported by the literature. Indeed, according with Bianchin et al. (2011), males confer higher valence ratings than females for both negative and positive stimuli (Bianchin & Angrilli, 2011). Although in this study the stimuli categories were just defined as "positive", "neutral" or "negative", it is a good source of comparison not only because the subjective ratings were obtained on visual stimuli taken from the IAPS, but also because the reference sample is similar to the one of this research. Not only the valence ratings produced similar results, but also the arousal ratings: in Bianchin et al. (2011) study, females rated with significantly higher scores than males on arousal negative stimuli. In the present research, females (compared to males) revealed higher ratings for mutilation stimuli, whereas males showed higher ratings only for the erotic stimuli. Furthermore, it has to be noted that, when looking at the categories of the Bianchin et al. (2011) study more in detail, it can be seen that the kinds of images shown for the "positive" category and the "negative" category are very similar to those shown in this study (for the "positive" category, images of erotic couples, naked people and extreme sports were shown, whereas for the "negative" category, images of guns, war scenes and blood/injuries were shown). A second study in line with the results obtained from our behavioral analysis can be found in Šolcová et al. (2017) work. From this research, however, only the data relative to the negative stimuli can be compared – as for positive stimuli, pictures and videos of a cute baby seal were shown, which does not belong in neither of the two categories we used for the positive category (erotic/extreme sports). Šolcová et al. (2017) negative stimuli were videos and pictures of mutilation, and the SAM reports for arousal showed higher median scores for females compared to males (Šolcová & Lačev, 2017). In general, it can be concluded that males, even when not taking into account the nature of the stimulus, appreciate more emotional stimuli due to the gender effect present when analyzing valence data. When taking into account the nature of the stimulus, the main difference can be found in the erotic category. A possible explanation of this findings can be found in the cultural and societal bias, according to which women have to not like this kind of images, whereas males are allowed to express their liking in a freer way. This bias could have forced female participants to rate erotic stimuli as less pleasurable than they actually would have do whether there was no societal pressure. Concerning arousal scores, it can be stated that, as expected, the neutral stimuli were the less arousing of all, whereas both positive and negative stimuli caused some levels of arousal, with erotic stimuli still showing higher ratings for males compared to females (which could still be due to the cultural bias above-mentioned), whereas for the negative category, mutilation stimuli caused the highest arousal, with higher ratings in women *vs.* men. It is noteworthy underlying that in males the highest arousal ratings were obtained in a positive category, whereas in females the highest arousal ratings popped out in a negative category, suggesting a greater female sensitivity for negative stimuli – a result not so different than others present in the literature (e.g., Stevens & Hamann, 2012).

3.2 Discussion of ERP results

As previously stated, we focused the attention of this study on the P1 and P300 component. Notably, the choice to study the P1 amplitude on parieto-occipital sites was rather similar to the one present in Bayer et al. (2014) study, which had as a primary goal to investigate the emotion effects in response to words, pictures and facial expressions. Almost the same electrodes were used, stating that the P1 amplitude onset was located at occipital electrodes PO9, PO7, PO8 and PO10 (Bayer & Schacht, 2014). This confirms that the P1 component reaches the maximum amplitude in the occipital region of the brain, and represents the electrophysiological marker of early visual encoding in primary and associative visual areas. Indeed, through the use of the software sLORETA, and regardless of stimuli, the P1 greater activation in women *vs.* men appeared localized in the right cuneus, specifically in BA 17, corresponding to the primary visual cortex. Considering the stimulus variable, for erotic, neutral and fear stimuli, women showed greater activation than men especially in the right cuneus in area BA 19, which is a visual association area having the role of feature extracting, shape recognition, attentional and multimodal integrating functions. Men, on the other hand, when comparing the activation in the left *vs.* right hemisphere, showed higher P1 amplitude in the left cuneus, particularly in area BA 18, a visual association area involved in the first stage for processing or feature extraction. Being the stimuli of this experiment visual, it is expected that major activity would be present in the occipital lobe, which is the one most involved in the visual processing. This right laterality is similar to that of Stevens et al. (2012). According to their fMRI study, in which these authors investigated hemispheric asymmetries while processing visual scenes, the left parahippocampal place area (PPA) seems to be more specialized in the processing form-abstract visual information, whereas the right PPA seems to be related to the form-specific visual processing, facilitating detailed scene analysis (Stevens, Kahn, Wig, & Schacter, 2012). Furthermore, the right PPA showed higher functional connectivity with posterior perceptual regions, including posterior and lateral occipital regions (Stevens, Kahn, Wig, & Schacter, 2012), corresponding to the areas where the highest P1 amplitude was found. Therefore, the asymmetry we see could be due to the nature of the stimuli presented, being rather specific and not requiring major abstract thinking. Across gender and across hemispheres, the highest amplitude was found in response to erotic and mutilation stimuli. The greater amplitude induced by mutilation stimuli is a result similar to the one from a study by to Carretié et al. (2004), who investigated *"the capability of emotional and nonemotional visual stimulation to capture automatic attention"* (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004). According to them, automatic attention is captured initially (meaning, a P1 component is found) in response to negative pictures, but not by positive or neutral ones. A reason why negative stimuli capture attention so early on can be found in the negativity bias, defined as *"[...] the tendency for negative personality* *traits to play a greater role than positive personality traits in determining overall impressions"* (APA, 2022). In a second study by Dan et al. (2012), investigating the attachment-related electrophysiological differences in emotional processing biases using ERPs, the ANOVA analysis revealed that the angry face stimuli presented to the participants produced greater P1 amplitude than the neutral faces (Dan & Raz, 2012), a result which matches the significant difference between mutilation *vs.* neutral stimuli in the present study. However, none of these studies found the greater amplitude shown in response to erotic stimuli, which belong to the positive category. A possible interpretation of this early greater activation depends on the particular content of erotic pictures: indeed, these are biologically relevant stimuli, essential for survival of the species, that probably induce appetitive action tendency, i.e., an approach towards the pleasant stimulus (Romeo et al., 2022).

Concerning the P300 amplitude, we found a higher amplitude, regardless of gender and stimuli, in the right hemisphere, suggesting an involvement of the attention system. Considering the stimulus contents, sport images have the greatest amplitude. A possible explanation of this pattern of activation is that, as erotic stimuli are processed early on (and proven by the greater P1 amplitude) depending on their intrinsic and biologically relevant meaning, sport stimuli are processed later (in the temporal window corresponding to the P300 component). This delayed processing could be due to their ambivalent nature, being categorized as positive stimuli when, in fact, those images of extreme activities could also cause a negative reaction in some participants (in particular, more anxious and shy individuals). Notably for the purposes of the present study, no gender effect appeared associated with P300 component, in line with the limited literature on this topic.

3.3 Conclusions

This research has been carried out with the main goal to investigate gender differences in the context of early ERP components, while subjects were involved in a passive viewing visual emotional task. In the literature focused on emotional processing, many studies can be found using ERPs to study the temporal dynamics associated with pleasant and unpleasant stimulus processing, also considering different kinds of populations (such as clinical samples suffering from a specific disease), and sometimes investigating the relationship between hemispheric dominance and/or gender. However, results are often inconclusive, as different approaches have been used, and various components have been considered. For these reasons, more experiments need to be made, including the variables that we tested in the present work, including, among others, gender, hemisphere laterality and various emotional stimuli. This kind of experiment can be easily replicated whilst modifying some variables in order to better clarify of these gender differences. For example, it could be interesting to measure not only ERPs, but also other psychophysiological indices, such as heart rate and skin conductance, to develop an more complete approach focused on the body physiological reaction to these kinds of images. The stimulus categories could also be modified, for example by showing cute images of animals as positive stimuli instead of erotic and extreme sport images, in order to investigate whether there is a change not only in ERP amplitudes, but also in valence and arousal ratings. Furthermore, neuroimaging techniques (such as PET and fMRI) could provide for an important contribute, in particular pinpointing the neuroanatomical brain circuits active during these processes.

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