



**IS A NEUTRAL EXPRESSION ALSO A NEUTRAL STIMULUS? A
STUDY WITH FUNCTIONAL MAGNETIC RESONANCE**

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7 **WITH FUNCTIONAL MAGNETIC RESONANCE**
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Abstract

Although neutral faces do not initially convey an explicit emotional message, it has been found that individuals tend to assign them an affective content. Moreover, previous research has shown that affective judgments are mediated by the task they have to perform. Using functional Magnetic Resonance Imaging in 21 healthy participants, we focus this study on the cerebral activity patterns triggered by neutral and emotional faces in two different tasks (social or gender judgments). Results obtained, using conjunction analyses, indicated that viewing both emotional and neutral faces evokes activity in several similar brain areas indicating a common neural substrate. Moreover, neutral faces specifically elicit activation of cerebellum, frontal and temporal areas while emotional faces involve the cuneus, anterior cingulate gyrus, medial orbitofrontal cortex, posterior superior temporal gyrus, precentral/postcentral gyrus and insula. The task selected was also found to influence brain activity, in that the social task recruited frontal areas while the gender task involved the posterior cingulate, inferior parietal lobule and middle temporal gyrus to a greater extent. Specifically, in the social task viewing neutral faces was associated with longer reaction times and increased activity of left dorsolateral frontal cortex compared with viewing facial expressions of emotions. In contrast, in the same task emotional expressions distinctively activated the left amygdale. The results are discussed taking into consideration the fact that, like other facial expressions, neutral expressions are usually assigned some emotional significance. However, neutral faces evoke a greater activation of circuits probably involved in more elaborate cognitive processing.

Introduction

The ability to recognize affective messages in the face is considered an essential skill in social interaction, not only to establish effective interpersonal communication but also to understand the emotional states of other individuals and predict their social behavior (Ekman 1982; Blair 2003). Many theoretical studies have suggested that this ability has been favored in evolution to confer adaptive advantages in intra-specific social development and cohesion (Fridlund 1994). Consequently, it has also been suggested that a neurobiological structure would have developed that specializes in accurately recognizing and expressing emotional messages, at least those valuable for an individual's survival, which correspond to the so-called basic emotions (Damasio 1998; Dalgleish 2004).

Therefore, over the past few years through patient studies with cerebral lesions (see e.g., Carvajal et al. 2009) and, especially, after the development of functional and electrophysiological neuroimaging techniques, evidence has been compiled to support the existence of the neural circuits employed to recognize emotions, specifically, emotional facial expressions. The brain regions involved in these circuits are being revealed in increasing detail, and suggest the implication of an extensive interactive network of cerebral structures (Vuilleumier&Pourtois, 2007). Hence, it has been shown that the perception of facial expressions is associated with the activation of areas of the occipital and superior temporal cortex (Labar et al. 2003; Winston et al. 2004), the prefrontal and somatosensory cortex (Esslen et al. 2004; Ioannides et al. 2004; Ishai et al. 2006; Geday et al. 2007); and limbic structures such as the insular cortex, amygdale or posterior cingulate cortex (Kesler-West et al. 2001; Adolphs et al. 2003; Britton et al. 2006).

In spite of evidence to support them, the relationships among these brain regions in the recognition process is not yet clear (Gobbini and Haxby, 2007; Atkinson and Adolphs, 2011). There are important differences in the procedures and the type of stimuli used and, consequently, interesting debates are still underway as to the specific role played by different brain regions and nuclei in the selective recognition of some emotions these (Fusar-Poli et al. 2009a, b; Dima et al. 2011). Other related controversial issues refer to the specificity of brain activation to emotional faces in comparison to neutral faces. To sum up, this refers to whether a neutral face is, in fact, a stimulus without an affective message, compared to facial expressions of emotions. Possibly, viewing an inexpressive face is not really an affectively neutral

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3 stimulus and could, therefore, activate some brain circuits shared with those involved in perceiving the
4 facial expression of an emotion. Likewise, in the so-called overgeneralization hypothesis, Zebrowitz
5 (1997), even proposes the existence of a tendency to perceive some neutral face features as emotional
6 expression traits. For example, Phillips et al. (1997) proposes that 100% neutral (muscles relaxed) faces
7 can appear slightly cold or sad. Similarly, when judges must assign emotional categories to facial
8 expressions and neutral faces, they assign an emotional content to neutral facial muscular configurations
9 (Carrera and Fernández-Dols 1994; Carvajal and Iglesias 2006). Taken together, the results of behavioral
10 studies indicate that evaluation of faces tends to be done in terms of the perception of subtle emotional
11 cues (Said et al. 2011).
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21 In accordance with behavioral studies perception of neutral faces would be expected to share a rather
22 similar cerebral activity to that triggered by emotional facial expressions (Schwartz et al. 2003; Ioannides
23 et al. 2004). However, different meta-analytic reviews of the relevant emotion neuroimaging literature
24 have reached somewhat different conclusions regarding which specific neural networks are associated
25 with each basic emotion (Phan et al., 2002; Murphy et al., 2003; Fusar-Poli et al., 2009a, b; Vytal and
26 Hamann, 2010).
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34 These interconnected brain areas could also be differentially activated depending on the specific demands
35 of the task (Atkinson and Adolphs, 2011). Hence, for example, the medial prefrontal cortex has been
36 shown to be differentially activated in tasks that test social decision-making (approachability of the face)
37 versus a cognitive task (gender decision) (Amodio and Frith 2006). More recently, Bzdok et al. (2011)
38 have also shown that brain functional networks activated by neutral faces are different depending on the
39 nature of judgments that subjects have to make. For example, they found that social judgments
40 (attractiveness and trustworthiness) selectively activate amygdale and inferior and ventromedial
41 prefrontal cortex compared to cognitive judgments (age).
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51 Based upon these previous results, our aim is to contribute to current knowledge of the cerebral basis of
52 the recognition of facial expressions. In particular, we are interested in investigating the specificity of the
53 brain activity triggered by emotional expressions and neutral faces. To control the possible modulatory
54 effect of judgments made by the participants we apply the same stimuli with two different tasks, one
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3 involving a social judgment (to decide whether the face presented is pleasant or unpleasant) and, another
4 related to a cognitive control condition (to indicate the gender of the shown facial stimuli). By using
5 functional Magnetic Resonance Imaging (fMRI), we compared brain activity to facial expressions of
6 frequent and basic emotions (happiness, anger and sadness) and neutral faces. Also, we compared
7 behavioral responses (reaction times), as a complementary measure of task difficulty (Habel et al., 2007).
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12 We expected neutral and emotional faces to activate rather similar brain areas, but some specific activity
13 to be found. More specifically, we expected emotional faces to evoke a greater activity in areas related
14 with more automatic aspects of emotional response, such as the amygdale. In contrast, neutral faces
15 would not only activate emotion related brain areas, but also regions probably involved in decision
16 making, such as the prefrontal cortex. Also, taking into account previous studies (Bzdok et al., 2011; Said
17 et al., 2011), we would expect to find differences in brain activation and reaction times as a consequence
18 of the task that individuals perform and, more specifically, increases in prefrontal brain activity for social
19 judgments and not for cognitive judgments.
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30 **Method**

31 **Participants**

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34 Nine male and 13 females participated in the study (mean age = 26.68; SD = 4.83; range: 21-38). One
35 subject was subsequently excluded from the analysis due to technical problems. All participants were
36 right-handed, with normal or corrected to normal vision, did not have a current or prior history of
37 neurological or psychiatric illness, and were not taking any medication or illicit substances. Written
38 informed consent was obtained from each participant. They were not paid for their participation. The
39 university research ethics committee granted ethical approval.
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49 **Materials and experimental paradigm**

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51 Visual stimuli were presented as black and white displays on a uniform white background. Face
52 photographs of eighteen individuals, each displaying a happy, angry, sad or neutral expression, were
53 selected from two standardized set of stimuli (Ekman and Friesen 1975; Bowers et al. 1991); in both
54 cases stimuli were defined by muscular prototypical configurations (in the case of emotional expressions)
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3 or by the absence of muscular activity (neutral faces). During fMRI acquisition the stimuli were presented
4 through MRI compatible goggles (VisuaStimDigital, Resonance Technology Inc, Northridge, CA) and
5 optic-fibre button boxes were used to record participant responses. Experiments were performed using
6 SuperLab software (Version 4.5, Cedrus Corp. CA).
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11 Stimuli were presented in a block design, blocked by condition (happy, angry, sad or neutral) to maximize
12 the statistical power (Hall et al. 2010; Jehna et al. 2011). Within each epoch, the valence of the facial
13 expression remained fixed. Each block consisted of 6 stimuli that were presented for 2500 ms with a 500
14 ms interval.
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21 Subjects were instructed to indicate by pressing one key with each hand whether the image presented was
22 a *man* or a *woman* (gender task), or how *pleasant* or *unpleasant* they thought each image was (social
23 task). A visual instruction text alerted the subject at the beginning of each block which of the two tasks
24 they had to respond. To avoid motor preparation effects, assignment of buttons to response categories was
25 counterbalanced across subjects.
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32 Each run started by viewing a blank screen for 15 s. Then, twenty-four 18 s task epochs (six blocks for
33 each category; three for the gender task, and three for social task) were presented in a fixed
34 pseudorandomized order. The tasks performed were fully counterbalanced across participants to control
35 for any order effects. Twelve rest epochs (15 s cross-hair fixations plus a 3 s instruction text) were
36 presented within each run, counterbalanced to ensure equal presentation before and after each
37 experimental epoch. Previous training with the tasks and the response schedule was performed outside the
38 scanner with a different set of images.
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48 **Image Acquisition**

49 The fMRI data were acquired on a 3.0T SignaHDx MR scanner (GE Healthcare, Waukesha, WI) using an
50 eight-channel head coil (GE Coils, Cleveland, OH). Functional images were obtained with a gradient
51 echoplanar sequence using blood oxygenation level-dependent (BOLD) contrast, each comprising a full
52 volume of 40 contiguous axial slices (3mm thickness, 0mm spacing). Volumes were acquired
53 continuously with a repetition time (TR) of 3 s [TE = 31 ms, flip angle = 90, field of view (FOV) = 21.7
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3 cm]. A total of 240 scans were acquired for each participant in a single session (12 min run), with the first
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5 five volumes subsequently discarded to allow for T1 equilibration effects. High-resolution T1-weighted
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7 spoiled gradient recall (SPGR) anatomical images were also obtained for each subject (184 1.8mm-thick
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9 axial images, TR=5.5, TE=2.3, FOV = 24 cm, 256 x 256 matrix).

10 11 12 **Data Analysis**

13 14 15 **Behavioral Data**

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17 A repeated-measures analysis of variance (ANOVA) with the four facial expressions (happy, anger, sad
18
19 and neutral) and the two tasks (social task and gender task) as the within-effect factors was used to
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21 compare reaction times.
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23 24 25 **fMRI Data**

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27 The data were analyzed using a general linear model in SPM8 (Wellcome Department of Imaging
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29 Neuroscience, London, UK, www.fil.ion.ucl.ac.uk/spm/) implemented in MATLAB 7.10 (Mathworks,
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31 Inc., Sherborn, MA). Individual scans were realigned, slice time corrected, normalized, and spatially
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33 smoothed by a 6 mm FWHM Gaussian kernel using standard SPM methods. The voxel dimensions of
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35 each reconstructed scan were 2 x 2 x 2 mm. Population inference was made through a two-stage
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37 procedure. At the first level we specified in a subject-specific analysis where the BOLD response was
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39 modeled by a boxcar waveform of 18 s representing a single block, convolved with a canonical
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41 hemodynamic response function plus temporal and dispersion derivatives. Rest condition served as
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43 baseline. Statistical parametric maps of the t statistic were generated for each subject and condition, and
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45 the contrast images were stored. For each individual, we determined the effect of the following contrasts
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47 of interest: happy-angry; happy-sad; angry-sad. These analyses revealed no statistically significant
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49 differences ($p < 0.05$ FWE) in any case. Then we focused on voxels that showed differences between
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51 “emotion” and “neutral” conditions and between these and rest epoch. We defined the “emotion” effect as
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53 the brain activation evoked by stimuli showing happy, angry and sad faces collapsed together. On the
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55 other hand, the neutral condition comprised only neutral faces.
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3 In a second level random effects analysis, a 2x2 (task by emotion) ANOVA model was used. We
4 constructed an F contrast to test for the main effects of task and emotion and a task by emotion
5 interaction, which indicates the extent to which the difference between activities when seeing both
6 emotional conditions (emotion vs. neutral) may vary while performing each task. In order to correct for
7 multiple comparisons in interpreting these results, two strategies were used. First, we used a threshold of
8 $p < 0.05$ Familywise Error Rate (FER) corrected for multiple comparisons for the entire brain volume to
9 assess the main effects of task and emotion. Then, to assess the interaction effect (task x emotion),
10 specifically for amygdale, a small volume correction (SVC) with a sphere of 10 mm radius was used. In
11 addition, we tested the similarities in brain activations between two contrasts performed: neutral
12 faces>rest, and emotional faces>rest. In order to test this possibility a conjunction analysis was
13 performed.
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25 The surviving activated voxels were superimposed on high-resolution structural magnetic resonance
26 (MR) scans of a standard brain (Montreal Neurological Institute, MNI). Anatomical identification was
27 performed with reference to the Talairach Daemon Software (<http://www.talairach.org/>), and AAL from
28 MRIcro software (<http://www.sph.sc.edu/comd/rorden/micro.html>).
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34 **Results**

35 **Behavioral Data**

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38 Means and standard deviations of reaction times to different faces in both tasks are recorded in Table 1. In
39 addition to the main effect of the task ($F(1,20)=16.89, p<.001$), the 2 (task) x 4 (emotion) ANOVA
40 revealed a significant interaction between task and emotion ($F(1,20)=5.35, p<.05$); subsequent
41 Bonferroni-test analyses only showed a significant effect of the emotion in the social task, where neutral
42 faces displayed a longer average reaction time than happy, anger and sad faces ($p < .05$).
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51 Insert Table 1 around here
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55 **fMRI Data**

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3 Functional images were analyzed by SPM8 using a general linear model applied at each voxel across the
4 whole brain.
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8 First, brain activity associated with rest epoch was subtracted from that evoked by neutral and emotional
9 faces. The random effects model revealed significant activations ($p < 0.05$ FWE corrected) in a wide
10 number of brain areas. Thus, neutral faces compared to rest epochs activated middle and inferior frontal
11 cortex, primary motor cortex (precentral gyrus), parietal inferior and occipital cortex, fusiform gyrus,
12 amygdale, putamen and cerebellum. On the other hand, emotional faces compared to resting condition
13 were associated with increased activity in a rather similar network, and adding insula and hippocampus.
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15 In order to test the similarities in brain activations between these two contrasts (neutral faces-rest, and
16 emotional faces-rest) a conjunction analysis was performed. This analysis revealed a wide pattern of
17 activation with a predominance of the right hemisphere ($p < 0.05$ FWE corrected; see table 2).
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30 Then, when the brain activity associated with viewing neutral faces was compared with that associated
31 with viewing emotional stimuli, the random-effects model revealed significant activation clusters
32 surviving a threshold of $p < 0.05$ FWE corrected, described in Table 3.
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41 The results showed more pronounced activation of facial expressions of emotion than neutral faces in the
42 left cuneus, right superior temporal gyrus, right cingulate gyrus, bilateral medial frontal gyrus, left
43 middle frontal gyrus, bilateral precentral gyrus, right postcentral gyrus and right insula; and more
44 pronounced activation of neutral expression than emotional faces in prefrontal regions (bilateral superior
45 frontal gyrus, right inferior and middle frontal gyrus), cerebellum, left superior temporal gyrus, bilateral
46 parahippocampal gyrus, left lobule occipital, right inferior parietal lobule and left mammillary body
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53 (Figure 1).
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3 Then, we compared the activation associated with each of the two tasks used (Figure 2).
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10 The social task compared with the gender task was associated with increased activation in a several
11 prefrontal areas (bilateral superior and inferior frontal gyrus and right middle frontal gyrus); the gender
12 task compared with the social task showed an increased pattern of activity in the right cingulate gyrus and
13 right semantic representation areas (middle temporal gyrus and inferior parietal lobule). In table 4 we list
14 clusters where SPM{F} for the main effects of task reached $p < 0.05$ (FWE corrected).
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24 An interaction between task and facial expression was identified in the left orbitofrontal cortex. Specific
25 contrasts indicated that the effect of the interaction was due to a differential response during the social
26 task; in particular, in comparison with emotional faces, there was greater left middle frontal gyrus activity
27 (BA=46; Talairach, X=-54, Y=18, Z=6; F= 24.26; z-score= 4.60) while participants processed neutral
28 faces. A $p < 0.05$ (FDR corrected) was applied for the interaction analyses. Interaction effects were also
29 found (SVC using a 10 mm sphere). A cluster comprising 37 voxels, within the search area survived the
30 correction located in the left amygdale (Talairach, X=-18, Y=-2, Z=-24; F=17.41; z-score=3.89). The
31 interaction effect was due to a differential response during the social task; in particular, emotional faces
32 showed greater activity than neutral faces.
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43 **Discussion**

44 The present study used functional magnetic resonance imaging to examine the neural substrate associated
45 with the perception of facial expressions of basic emotions. We focused our attention on the evaluation of
46 faces with neutral expressions compared to emotional expressions. Neuroimaging data obtained suggest
47 that the perception of neutral faces is related to the recognition of emotional facial expressions. Both rely
48 on a rather similar face-responsive network, which includes areas that seem to be relevant in processing
49 identity, and others involved in detecting emotion. In general, we observed a wide and common right
50 lateralized activation pattern in response to emotional expressions and neutral faces, which included
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3 frontal, parietal, occipital and temporal regions. Nonetheless, our findings also revealed divergence in the
4 specific pattern of activation during the processing of each type of facial stimuli, as well as a marked
5 variability in the regional activation between the tasks we employed.
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10 First, we identified by conjunction analysis the set of areas of face-responsive, independently of the
11 emotional content and task. The results revealed a widespread network distributed across the right
12 hemisphere, which included the occipital face area (OFA), frontal gyrus (middle and inferior), inferior
13 parietal lobule, middle temporal gyrus, precentral gyrus and uncus. In addition, the cerebellum and the
14 insula were also active in both hemispheres during facial processing; while, in the left hemisphere, the
15 only region activated was the medial frontal gyrus. These areas are included in the core and extended face
16 processing brain system, according to the Haxby et al. model (Haxby et al. 2000; Gobbini and Haxby
17 2007). Furthermore, these data support the proposed right hemispheric dominance in face perception
18 (Murphy et al. 2003).
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29 Some of the regions identified by the conjunction contrast have been associated either with identity or
30 emotional face processing in a wide range of studies (LaBar et al. 2003; Calder and Young 2005; Ishai et
31 al. 2005; Atkinson and Adolphs 2011; Said et al. 2011). Hence, OFA is the first stage in a hierarchical
32 faces perception network and represents facial components, so is essential for facial identity (Li et al.
33 2010; Pitcher et al. 2011). Complementarily, the posterior portion of the middle temporal gyrus has been
34 associated with the perception of facial expressions (Hein and Knight 2008; Said et al. 2010). These data
35 show that when individuals are confronted with a face, including a neutral face, areas related to facial
36 expression are also activated, together with those involved in identity perception. We could, therefore,
37 deduce that when we perceive a neutral face, as well as processing its identity, we can also try to assign it
38 an emotional value, which is logical given the importance of this information in human social interaction
39 (Zebrowitz 1997).
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50 51 **Neutral and emotional activation**

52 However, our aim was mainly to identify brain differences as a function of the neutral and emotional
53 facial perception. In this line, we observed that viewing neutral faces evokes coactivations between a
54 network of frontal cortex and several other areas, including superior temporal gyrus (STS), cerebellum,
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3 parahippocampal gyrus and mammillary body compared to facial expressions. Most of these areas have
4 recently been referred to as integrated in an extended system for both, face and voice perception (Ethofer
5 et al., 2013). So, according to this wide network processing neutral faces seems to evoke a complex
6 representation.
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11 Regarding the prefrontal cortex, we particularly found dorsolateral, ventrolateral and orbitofrontal
12 activity. All together, the lateral/orbitofrontal cortex, has been implicated in several psychological
13 functions, such as encoding novel information, evaluative processing, decision-making and face
14 processing (Rolls, 2004; Ishai 2007). Additionally, each specific frontal region reveals dissociable roles:
15 motor functions of the supplementary motor area are well documented, and activity in this area may
16 reflect motor imagery and inhibited motor output during internal simulation (Nachevet al. 2008).
17 Although this area has been found to be commonly activated across different emotional faces, a greater
18 response to neutral faces has also been reported (Fusar-Poli et al., 2009a, b). Regarding the orbitofrontal
19 cortex (OFC) activity, it has been suggested to constitute a neural interface linking sensory areas with
20 brain regions implicated in the generation of behavioral responses, such as the above mentioned
21 supplementary motor area. The OFC has been implicated in a broad range of functions including a key
22 role for the active judgment of social signals (Zald et al., 2012). THE OFC has also been attributed a
23 crucial role in the top-down processing of faces regulating the activities of the OFA and the fusiform face
24 area (FFA). This top-down face processing is required to interpret ambiguous faces stimuli, imagined face
25 or to detect impoverished face stimuli (Li et al., 2010).
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42 In addition, in our study, the temporal pole (anterior portion of superior temporal gyrus and
43 parahippocampal cortex) responded more actively to neutral faces. The parahippocampal gyrus, has been
44 consistently associated with the perception of human faces and the superior temporal gyrus (STG)
45 integrates into the superior temporal sulcus (STS), a cortical region especially involved in the
46 interpretation of faces (Haxby et al., 2000). In the same line, it has recently been proposed that the role of
47 the STS in human cognition and emotion is to process "social attention" which is a crucial human skill for
48 making inferences with respect to others' goals, intentions and actions (Hein and Knight 2008; Iidaka
49 2012). It seems, therefore, that the perception and judgment of neutral faces is a complex social task that
50 involves greater cognitive effort than emotional faces regardless of the type of task performed.
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5 Interestingly, we also found an increased brain activity in mammillary bodies and cerebellum to neutral
6 faces in comparison to emotional expressions. Both areas have been consistently related with emotional
7 and memory processing in different studies, but interpretation of their role in facial recognition remains
8 unclear (Fusar-Poli et al. 2009a, b). Regarding mammillary bodies, clinical studies repeatedly show that
9 lesions in this diencephalic region can impair recognition memory (Aggleton et al. 2011), but their role in
10 emotional recognition has not been determined. A recent meta-analysis of neuroimaging studies,
11 examining sex differences as a function of positive vs. negative emotional valence, showed men's and
12 women's responses to all emotional stimuli in an extended cluster of regions including the mammillary
13 body (Stevens and Hamman, 2012). It has also been described that stroke seemingly confined to
14 mamillothalamic tract and anterior parts of lateral thalamus produced visuospatial memory deficits,
15 including poor face recognition (Daum and Ackermann 1994). Also, Beglinger et al. (2006) observed
16 severe and persistent recall deficits in the Warrington Recognition Memory Test for faces and words in a
17 patient with bilateral loss of the mammillary bodies. Although these data suggest a role for mammillary
18 bodies in emotional processing and face recognition, to our knowledge, this is the first neuroimaging
19 study that shows its implication in face processing.
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34 Otherwise, our results further support the involvement of the cerebellum in facial processing. We found a
35 neural response in the cerebellum in conjunction analysis, but also, the right cerebellum was activated
36 significantly more in response to neutral faces than to emotional faces. The unspecific activation to
37 different faces and facial expressions points to a general role of the cerebellum in cognitive and emotional
38 processing (Turner et al. 2007). However, recent clinical and neuroimaging research has tried to establish
39 its precise contribution to each of the non motor functions. On the one hand, several studies indicate that
40 the cerebellum might play a role in experiencing and controlling emphatic emotions. Cerebellar regions
41 are required during subliminal and task-irrelevant emotional face processing, which could explain
42 cerebellar activation found in conjunction analysis (Pantazatos et al., 2012). On the other hand, Schraa-
43 Tam et al. (2012) suggest the potential role of the cerebellum in cognitive control for goal-directed
44 behavior as required, for example, in observing and reacting to another person's expressions.
45 Additionally, reciprocal connections between the cerebellum, the dorsolateral prefrontal cortex and
46 anterior temporal lobe have been described (D'Angelo and Casali, 2012). Precisely, these circuits
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3 coincide with activations we have found to neutral faces and, as discussed before, may contribute to
4 cognitive control and decision-making to complex stimuli.
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8 By contrasting to the processing of neutral faces, emotional faces seem to require the integrated activity
9 of frontooccipital regions and limbic regions. During the neural coding of facial affect, five specific areas
10 are concomitantly activated, the cuneus, the anterior cingulate gyrus, pre/postcentral gyrus, insula and
11 medial OFC, to a greater extent than neutral faces. The cortical network identified as contributing to the
12 processing of emotional faces is highly consistent with a number of previous studies (Fusar-Poli, 2009a,
13 b).
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21 With respect to the insular cortex and anterior cingulated gyrus, both limbic regions have been implicated
22 in the rapid processing of salient facial emotional information (Fan et al., 2011). For the insular activity,
23 this has been reported during the processing of negative facial expression, like disgust and angry faces
24 (Fusar-Poli et al., 2009b) and has, recently, been implicated in the processing of unattractiveness and
25 negative personality faces (Tsukura et al., 2012). Regarding the cingulated cortex, anterior regions are
26 considered as “transition regions” wherein cognitive and affective processes are integrated (Torta and
27 Cauda 2011), and are also involved in rapid processing of facial emotional information (Fan et al. 2011).
28 The cingulated cortex is a richly interconnected heterogeneous region and Vogt et al. (2005) suggest that
29 different parts of the cingulate cortex could be related in activities that are shared by several tasks rather
30 than by specific ones. To support this idea it has been suggested that the anterior cingulated cortex works
31 together with limbic sensory and motor regions and plays a complementary role in the production of
32 interoceptive and subjective feelings (Torta and Cauda 2011),
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45 Also, we observe that the cuneus, motor, pre-motor and nearby somatosensory cortex show functional
46 coactivation during the perception of facial expressions. These regions may have a role in emotion
47 recognition through the mirror neuron system. In particular, cuneus activation has been related to the
48 theory of mind during imitation (Vrticka, et al., 2013). When simply looking at expressive faces images,
49 people mimic the facial expression, by producing microexpressions (Dimberg et al. 2000). It could,
50 therefore, be suggested that recognition of the expression and its subsequent imitation would occur more
51 automatically in response to facial expressions with a clear emotional content than to neutral faces. In
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3 fact, we found motor cortex activity only to emotional faces, supporting this possible active simulation
4 processes. In the same line, a greater response has been described in the left motor cortex to fearful than
5 to neutral faces in a priming task (Fan et al. 2011).
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10 It is also worth noting STS and OFC activity in emotional as well as in neutral face processing, although
11 different subregions are implicated in one or another. Consistent with previous research, while neutral
12 faces recruit anterior temporal areas, posterior STS is involved in a response to emotional faces. The latter
13 has been related to the processing of changeable features of faces, such as the expression (Hein and
14 Knight, 2008). Regarding the prefrontal cortex, in contrast to the right lateralized pattern to neutral faces,
15 to facial expressions we located the involvement of medial regions that have a well-established role in
16 emotional processing (Phan et al., 2002; Phillips et al., 2003; Dima et al., 2011). Recently, by means of
17 meta-analytic connectivity modeling, a differentiation has been established between the pattern of
18 functional connectivity for the medial and for the lateral OFC (Zald et al., 2012). Lateral OFC showed
19 coactivations with a network of prefrontal regions and areas involved in cognitive functions we found to
20 be involved in processing neutral faces in this work. In contrast, medial OFC showed connectivity with
21 autonomic and limbic regions. Taken together, these results indicate a relevant role for the prefrontal
22 cortex in the perception of emotional and non-emotional faces, and support the existence of different
23 functional circuits in this intricate orbitofrontal region.
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38 **Task effects**

39 In this work we have also observed a clear modulation of the activity in different brain regions, according
40 to the type of perceptual decision-making tasks we employ. On comparing the tasks, we observe that the
41 social task evokes greater activity in the superior, middle and inferior frontal gyrus while the gender task
42 differentially requires the posterior cingulate, inferior parietal lobule and middle temporal gyrus.
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49 The group of areas recruited by the social task (all located in the prefrontal cortex) could be linked to the
50 perceptual representation of faces for the generation of knowledge in relation to its social significance.

51 Supporting this, it is well known that the prefrontal cortex has been implicated in many cognitive
52 functions, including holding spatial information, working memory, response selection, and the
53 verification of representations that have been retrieved from long-term memory (Ramnani and Owen,
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2004). Furthermore, our finding concurs with the results of a recent meta-analysis highlighting the bilateral activation pattern at the level of the frontal cortex, during comprehension of social signals in facial expressions (Sabatinelli et al., 2011). Thus, in our work we locate several dorsolateral prefrontal cortex areas, which have been related to featural aspects (e.g., shape of the mouth) and the configural processing of faces (spatial interrelationships between features) (Renzi et al., 2013). Another of the most active cortical areas in social task was the middle prefrontal cortex, which has also been implicated in emotional processing (Fan et al., 2011). In addition, the inferior frontal gyrus handles semantic information and several studies have shown that it can be activated by expressive face processing (Ishai et al., 2002; Fusar-Poli et al., 2009b). This set of data support the observations made by Dima et al. (2011) highlighting the role of the prefrontal cortex during affective processing, and questioning the prevailing amygdalocentric model of affective processing. Based on the important role of the frontal region in social tasks and its complex functions, it may be assumed that the attribution of a pleasant or unpleasant character to a face conveys it a higher-level representation than a more automatic and effortless gender decision.

Support for the idea that this frontal activation may be related to cognitive load may also come from the behavioral data, specifically when neutral faces are presented. The participants showed greater reaction times to neutral versus emotional faces in social task. We also found that neutral faces activate dorsolateral frontal regions particularly engaged in the assessment of ambiguously expressed emotion (Nomura et al., 2003). On the basis of this evidence, we can argue that processing neutral faces in the social task may involve more executive control than the gender task.

Regarding the gender task, Kaul et al. (2011) suggest that information about facial gender is represented in almost all regions of the face network. Nonetheless, our data show that some regions, such as the posterior cingulate and the temporal parietal junction, with well known strong functional connections between them, may play a more important role in the gender decision task. Activation of these areas may reflect visuospatial processing and episodic memory involvement during evaluation of the traits of each gender. Supporting this idea, the activated posterior parts of the cingulate have been associated with saliency detection, visuospatial and episodic memory functions and face discrimination (Torta and Cauda 2011). Previously we have mentioned a preferential participation of the anterior region characterized by

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3 its involvement in attention and rapid processing of salient facial emotional information (Fan et al. 2011).
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5 Then, the cingulated cortex would be considered as a higher order associative area which would explain
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7 its great significance in the gender task and also in the analysis of emotional faces.
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11 In any case, this finding, together with that previously mentioned, suggests that the processing of facial
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13 expressions depends on broad neural circuits and areas with interactive and complementary functions
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15 which may vary according to task or context (Vuilleumier and Purtois 2007; Atkinson and Adolphs
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17 2011). To conclude, the results of this work suggest that emotionally inexpressive faces are not perceived
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19 very differently from emotional facial expressions and their recognition requires at least a partially shared
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21 neural network. However, neutral faces activate other frontal and temporal brain regions that could reflect
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23 a more elaborate cognitive processing not required for facial expressions of basic emotions, and
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25 emotional faces have been found to activate some specific limbic brain areas. We have observed these
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27 differences independently of the task performed, although to a greater extent when the participants are
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29 required to make an explicit social judgment. We, therefore, consider that further studies are needed to
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31 ascertain the coordinated role of the broad cluster of different areas and neural networks implicated in
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33 facial and emotional recognition.
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Table 1. Mean and Standard Deviation of Reaction Times (milliseconds) to emotions and neutral faces in the social and gender tasks.

Task	Faces			
	Neutral	Happiness	Anger	Sadness
Social	1139.2 (304.5)	890.9 (199.5)	966.5 (214.3)	998.9 (223.7)
Gender	877.6 (195.5)	861.4 (201.2)	835.9 (197.3)	883.4 (234.4)

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Table 2. Results of the fMRI conjunction analysis (neutral faces-rest and emotional faces-rest).
L: left, R: right, Mid: Middle

Brain Regions activated	Hemisphere	BA	N° Voxels	Talairach			T	z-score
				x	y	z		
Occipital lobe	R	18	6160	14	-102	6	12.62	>8
Occipital lobe	L	18		-16	-102	4	12.16	>8
Lingual Gyrus	R	17		12	-98	-12	11.55	>8
Middle Frontal Gyrus	R	46	65	46	26	24	5.58	5.32
Middle Frontal Gyrus	R	9		48	30	32	5.15	4.94
Middle Frontal Gyrus	R	9	27	56	14	34	5.39	5.15
Medial Frontal Gyrus	L	6	683	-8	2	56	8.17	7.43
Medial Frontal Gyrus	R	6		6	0	60	7.78	7.13
Superior Frontal Gyrus	R	6		10	8	56	7.06	6.55
Inferior Frontal Gyrus	R	9	134	44	4	28	5.91	5.60
Precentral Gyrus	R	6	173	44	-8	60	6.04	5.71
Precentral Gyrus	R	6		52	0	46	5.96	5.64
Precentral Gyrus	R	6		48	0	56	5.47	5.22
Precentral Gyrus	L	6	2	-48	-8	54	4.93	4.74
Precentral Gyrus	L	6	5	-42	-10	60	5.27	5.04
Inferior Parietal Lobule	R	40	26	48	-46	46	5.36	5.12
Inferior Parietal Lobule	R	40	192	34	-54	42	5.94	5.63
Superior Parietal Lobule	R	7		34	-64	50	5.34	5.10
Superior Temporal Sulcus	R	21	83	48	-46	2	5.87	5.56
Uncus	R	28	30	18	-6	-24	6.07	5.74
Insula	L	13	32	-34	14	12	5.60	5.33
Insula	L	13	4	-44	-6	10	5.13	4.92
Insula	R	13	8	34	20	4	5.13	4.92
Cerebellum	L		88	-10	-78	-36	5.77	5.48
Cerebellum	L			-10	-86	-28	5.55	5.29
Cerebellum	L			-6	-84	-18	5.18	4.96
Cerebellum	R		10	8	-32	-8	5.20	4.98

Table 3. Clusters showing main effects of emotion.. R: rightL: left, R: right.

Greater activity in response to facial expressions of emotions than neutral faces

Brain Regions activated	H	BA	N° Voxels	Talairach			T	z-score
				X	Y	Z		
Precentral Gyrus	R	4	25	42	-18	42	5.35	5.12
Precentral Gyrus	L	4	42	-40	-18	36	6.03	5.71
Postcentral Gyrus	R	5	84	22	-44	66	6.03	5.71
Anterior cingulate	R	32	149	8	40	4	6.57	6.16
Cuneus / lob occipital	L	18	7038	-12	-74	24	9.09	>8
Superior Temporal Gyrus	R	22	224	58	-2	2	6.47	6.08
Medial Frontal Gyrus	L	10	39	-10	54	-4	5.59	5.32
Medial Frontal Gyrus	R	10	79	6	56	-6	6.0	5.68
Middle Frontal Gyrus	L	6	90	-24	14	52	6.41	6.03
Insula	R	*	69	36	-14	2	6.08	5.75

Greater activity in response to neutral faces than facial expressions of emotions

Brain Regions activated	H	BA	N° Voxels	Talairach			T	z-score
				X	Y	Z		
Superior Temporal Gyrus	L	38	1157	-50	16	-8	8.20	7.46
Inferior Frontal Gyrus	R	47	3699	38	22	-4	9.75	>8
Superior Frontal Gyrus	L	6	1290	-42	-12	62	7.89	7.23
Superior Frontal Gyrus	R	6	1610	4	6	60	9.67	>8
Superior Frontal Gyrus	R	10	70	34	56	26	6.28	5.92
Inferior Frontal Gyrus	L	10	58	-48	46	-2	6.40	6.02
Middle Frontal Gyrus	R	11	43	46	46	-10	5.79	5.50
Cerebellum	R	*	8214	36	-52	-34	11.31	>8
Mammillary Body	L	*	7	-8	-6	-10	5.07	4.87
Parahipocampal Gyrus	L	34	205	-16	-6	-22	7.53	6.94
Parahipocampal Gyrus	R	28	88	16	-6	-24	7.13	6.62
Lob occipital	L	18	94	-16	-102	4	8.19	7.45
Lingual Gyrus	L	18	38	-8	-100	-10	7.08	6.59
Inferior Parietal Lobule	R	7	68	34	-56	44	5.96	5.65

Table 4. Clusters showing main effects of task. L: left, R: right

Greater activity in response to social task than gender task

Brain Regions activated	He	BA	N° Voxels	Talairach			T	z-score
				X	Y	Z		
Superior Frontal Gyrus	R	8	39	6	46	46	6.48	6.09
Superior Frontal Gyrus	L	8	360	-2	24	50	7.25	6.72
Superior Frontal Gyrus	L	6	25	-10	12	64	6.07	5.74
Superior Frontal Gyrus	R	6	40	12	22	62	6.06	5.73
Middle Frontal Gyrus	R	9	380	54	14	32	6.94	6.47
Superior Frontal Gyrus	R	10	15	20	58	22	5.19	4.98
Superior Frontal Gyrus	L	45	415	-54	18	6	7.06	6.57
Inferior Frontal Gyrus	R	45	154	54	28	2	6.80	6.35

Greater activity in response to gender task than social task

Brain Regions activated	H	BA	N° Voxels	Talairach			T	z-score
				X	Y	Z		
Posterior Cingulate	R	31	78	8	-30	46	6.03	5.71
Superior Temporal Gyrus	L	22	14	-66	-34	12	5.05	4.85
Inferior Parietal Lobule	R	40	21	66	-26	24	5.59	5.33
Middle Temporal Gyrus	R	21	20	68	-28	2	5.76	5.47
Caudate	R	*	4	20	-40	12	5.16	4.95

Figure 1: Group activation map showing activated brain regions in emotion. Neutral>Emotion is shown in red. Emotion>Neutral is shown in blue. Images thresholded at FWE $p < 0.05$. Neurological convention is followed (left side of the brain is shown on the left side of the figure). Results are visualized using xjView toolbox (<http://www.alivelearn.net/xjview>).

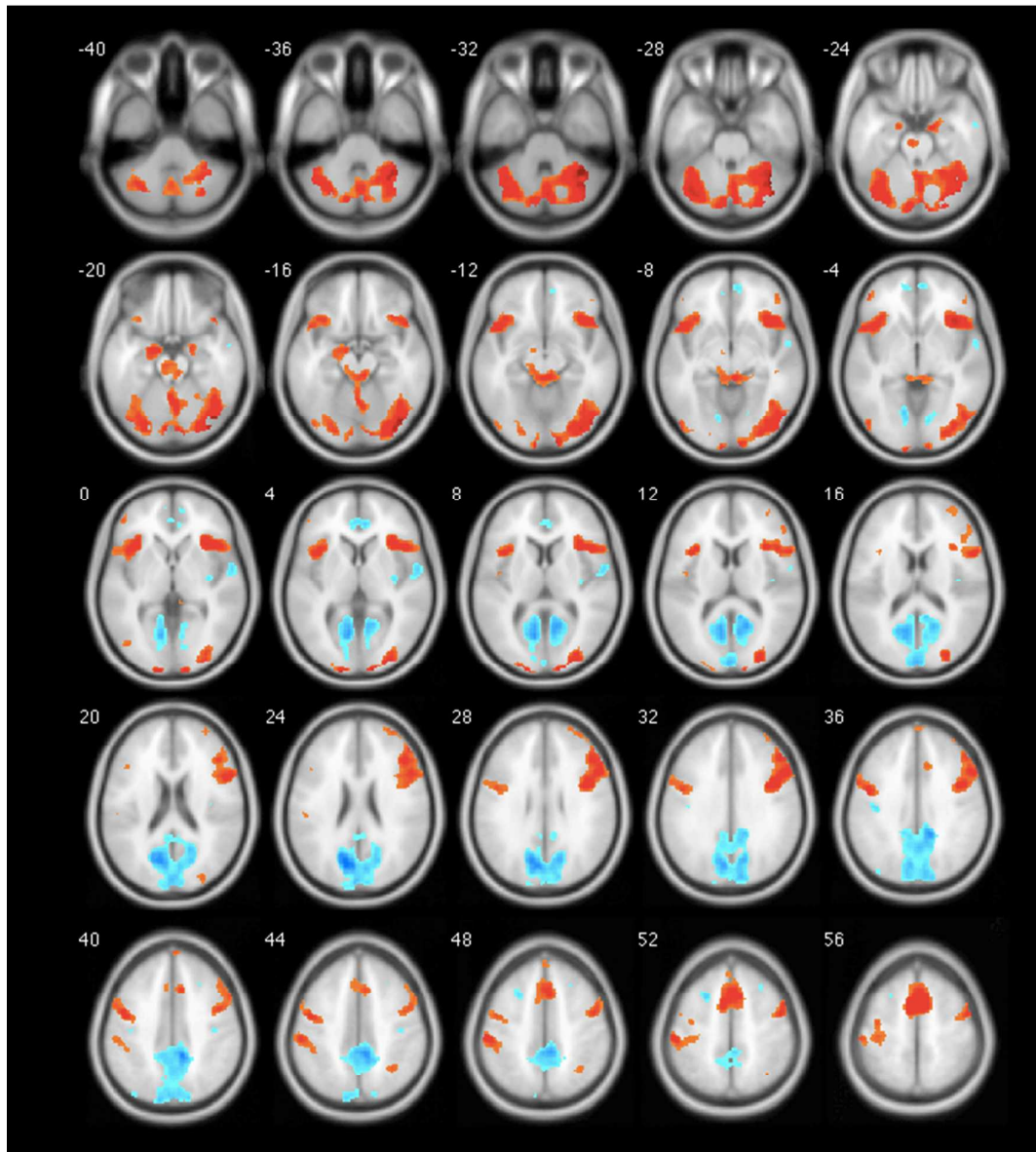


Figure 2: Group activation map showing activated brain regions in tasks. Social>Gender is shown in blue. Gender>Social is shown in red. Images thresholded at FWE $p < 0.05$. Neurological convention is followed (left side of the brain is shown on the left side of the figure). Results are visualized using xjView toolbox (<http://www.alivelearn.net/xjview>).

