Basic emotions: differences in time sequence and functional imaging with low resolution brain electrical tomography (LORETA)

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Abstract

The aim of the present study is to investigate the relationship between the time course of brain activation during the observation of pictures depicting scenes associated with the four basic emotion of happiness, sadness, fear and disgust. Twenty-nine right-handed volunteers (17 male, 12 female; mean age 24.6 years) took part in the study. To study the time course of the affective processing the low resolution brain electromagnetic tomography (LORETA) has been used. Each emotional condition has shown specific activation patterns in different brain regions, changing over time. Our findings are in good agreement with other brain-imaging studies (PET/fMRI) but with the advantage to investigate the temporal evolution of the emotional process in the millisecond range. The results showed that the time sequence of activations is different and characteristic for each emotion conditions.

Keywords: Brain areas; low resolution topography; Emotional processing; basic emotions

Introduction

An important issue in the psychology and neuroscience of the emotions is what are the irreducible elements of emotional experience or, in other terms, what is the structure of the emotions.
In the last decades neuroimaging techniques have open a new way to search distinctive and separable brain circuitry for each emotion category and to find a clear picture of the structure of the emotions. These results were obtained with various methods: fMRI researches found different brain areas activated during the processing of different and distinct emotions for happiness, sadness, fear and disgust but with some inconsistent evidences in the type of differentiation (Phan et al. 2002; Murphy et al. 2003; Wager et al. 2003); event-related potential (ERP) studies found consistent effect of the arousal occurring at longer latencies but inconsistently valence effects at several latency ranges (for a review see Olofsson et al 2008); EEG studies found differences for negative and positive emotional stimuli (Costa et al. 2006; Costa et al. 2008). However, until now, there are not a clear and definitive response to the question about the structure and the basic elements of the emotions.
One component, not much considered, which may play a role in emotional processing is the temporal evolution of different and distinct emotions. It is possible for the brain region involved in the emotional process to be activated in time specific sequences. This could be a fundamental element useful in the distinction between different emotional state. If we consider the emotion as an episodic, relatively short-term, biologically based pattern of perception, experience, physiological activity in response to specific physical stimuli (Keltner & Gross, 1999), it is evident that timing should be take in account when we study the emotion. In principle then it should be possible to discriminate among different emotional states, not just from the areas involved, but also by different onset times and duration. As stated by Ekman (1984) emotions usually last only a few seconds and can have different timing depending on their type.
Esslen and colleagues (2004) investigated brain regions and time sequences associated with the observation of emotional and neutral faces and the task of self-generating the same emotion displayed by the faces by low resolution brain electromagnetic tomography (LORETA) introduced by Pasqual-Marqui et al. (1994). The results show large bilateral activation in the PFC and temporal cortices for all the emotions, accompanied by emotion-related differences in the time segments: anger and fear were associated with a late onset and significant cortical activation, suggesting a preceding subcortical activation. As discussed by these authors, these results could be partially linked to the specific method used to elicit emotion.
As underlined by Davidson et al. (1999), the perception of emotional information must be carefully distinguished from the production of emotion, and the presentation of emotional facial expressions need not to elicit an actual emotional response in the observer.
These considerations, encourage to proceed in investigating how neural activity in specific areas may change over time during emotional stimuli processing, and, in particular, during the passive observation of emotional scenes, instead than facial expressions (Esslen et al. 2004), without demanding any cognitive task.
The aim of this explorative study was to investigate the brain response to the observation of emotional pictures using the low resolution brain electromagnetic tomography (LORETA) that exploits high time resolution as in the EEG method and the localization of neuronal activity. In particular we investigated the relationship between the time course of brain activation and the passive observation of pictures depicting scenes of happiness, sadness, fear, and disgust and to elucidate the temporal dynamics of the neural network involved in the emotional processing. We choose these emotion because most of the emotion theorists do consistently include these four emotions.as biologically based. The hypothesis is that there are different cortical circuitry and different time behaviour for the different emotion.

Materials and method

Subjects

Twenty-nine right-handed volunteers (17 male, 12 female; mean age 24.6 years) took part in the study. All subjects had no personal history of neurological or psychiatric illness, no drug or alcohol abuse, no current medication, and had normal or corrected-to-normal vision. Handedness was assessed with the "measurement of Handedness" questionnaire [4]. All subject were informed about the aim and design of the study and gave their written consent for participation. The Ethic Committee of the Department of Psychology of the University of Turin gave approval for the study.

Stimuli

Standardized IAPS stimuli (Lang et al, 2005) showing happy, sad, disgust, fear and neutral pictures, were pre-selected. The reason to select only these kind of emotional pictures were that most theorist do consistently include these five emotions among the basic emotions**.**The stimuli pre-selected were tested on a sample of judges (N=30), who labelled the emotion experienced viewing the pictures. There was high concordance between the expected and the self-reported emotions (k-Cohen =.89, $p<.001$).

Procedure

Stimuli were presented on a 21 inch computer screen. Subjects were seated at 1 m distance from the screen with their head comfortably positioned in a chin and forehead rest. The task was simply to passively view the pictures, without demanding any cognitive task: subjects were instructed to sit quietly and to look at the centre of the screen to reduced muscle and eye movement artefacts.
Each picture was shown on screen for 500 ms, followed by 1 sec of a black screen. The stimuli for the four emotional categories were presented in a block design: the emotion-specific pictures were randomly assigned to their corresponding block both between and within subjects; each block consisted of presenting 20 neutral pictures followed by 40 pictures expressing one of the four emotions. The order of presentation of the four blocks was randomized between subjects. A break of approximately 5 min. separated each successive block to allow subjects relaxing and returning to the baseline level. The block design was been used in other studies (e.g., Sprengelmeyer et al., 1998; Sutton et al., 1997, Esslen 2004). The reason to use block design was to reduce the chance of confusion and to increase the chance to obtain results of pure basic emotions (Paradiso et al., 1999).
After the EEG recording, a self-report was used to assess the subjective emotional response to pictures. The metric properties were comparable to those used for IAPS: subjects viewed again the pictures and rated the pleasantness of their own emotional experience on a 9-point Likert scale ranging from 1 (very unpleasant) to 9 (very pleasant) and the arousal level from 1 (not at all, very calm) to 9 (fully experienced emotion, very excited). Additionally, subjects indicated the intensity of emotion they experienced on a rating scale, including the basic emotions of happiness, sadness, anger, fear, and disgust (from 1 indicating that the emotion was not at all present, to 9 indicating that it was felt very strongly).

EEG measurements

EEG was recorded from 19 sites (Fp1, Fp2, F7, F8, F3, F4, Fz, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz, O1, O2). A ground electrode was attached to the center of the forehead. Vertical EOG was measured with electrodes 2 cm above and below the middle of the right**.** The electro-oculograms (EOG) was measured in order to facilitate ocular artefacts scoring, and remove them from the EEG recordings.

EEG and EOG signals were amplified by a multi-channel bio-signal amplifier (band pass 0.3-70 Hz) and A/D converted at 256 Hz per channel with 12-bit resolution and 1/8-2 μV/bit accuracy. The impedance of recording electrodes was monitored for each subject prior to data collection and the threshold was always kept below 5 KOhms. Recording were performed in an electrically shielded room with dim illumination.

Postprocessing

Off-line all artefact-free EEG epochs of 1 sec duration were identified by careful visual inspection of the raw data on a computer display. Epochs with eye-movement, eye-blink, muscle and head movement artefacts were rejected. The accepted epochs were recomputed to average reference and digitally band passed to 1-45 Hz.

Based on the scalp-recorded electric potential distribution, the exact low resolution brain electromagnetic tomography (LORETA) software was used to compute the cortical three-dimensional distribution of current density. The method is a discrete, three-dimensional (3D) distributed, linear, weighted minimum norm inverse solution. The description of the method are described in Pasqual-Marqui et al. (1994). This procedure computes from the EEG recording the three dimensional distribution of current density a linear solution constrained by the request that the current density distribution be the smoothest one among all the solutions. LORETA use a three-shell spherical model registered to the digitised Talaraich atlas with a spatial resolution of 7 mm; this results in a three-dimensional image consisting of 2394 voxel.

Analysis

To assess the difference between the different conditions we used a measure of dissimilarity **denoted TANOVA (topographic analysis of variance)** (Strik et al. 1998). This is a global measure of difference between two scalp potential maps. Statistical significance for each pair of maps was assessed nonparametrically with a randomisation test corrected for multiple comparison. This procedure was used to found what time segment differed significantly between emotional condition and the neutral condition.

When the TANOVA found a significant time segment an averaged LORETA image was defined as the average of current density magnitude over all instantaneous images for each voxel. The statistic was based on voxel-by-voxel t test of LORETA images between each emotion vs. neutral.

The methodology used is non-parametric. It is based on estimating, via randomization, the empirical probability distribution for the max-statistic (the maximum of the *t* statistic), under the null hypothesis. This methodology corrects for multiple testing (i.e., for the collection of tests performed for all voxels, and for all time samples) using bonferroni correction. Due to the non-parametric nature of the method, its validity need not rely on any assumption of Gaussianity (Nichols and Holmes 2002). The p values at a voxel level of $p< 0.01$ with a minimum of 10 voxels per cluster (extent threshold) were considered statistically significant**.**

Results

The results of the analysis of the self-report showed that the emotional states induced in the subjects correspond to the expected emotions. Target emotions were correctly identified with high concordance between expected and the self-reported emotions (k-Cohen = .77, $p<.01$).

The mean and standard deviation for valence and arousal are shown in table 1.

Tab 1

The results of analysis among the four emotions vs. neutral showed that the observation of each emotional picture was accompanied by specific temporal dynamics involving differences in the number of significant segment, in their onset time, and durations (Fig. 1). The negative stimuli of

disgust, and fear presented only two onset time around 250 ms. Happiness and sadness shared the latest onset times, with sadness that induced the longest time segment from 400 to 500 ms.

Fig 1

A first overall comparison between emotional and neutral conditions was performed on the whole time course of EEG responses, averaging all instantaneous images acquired during the presentation period (70-500 ms post stimulus interval) Table 2. In all significant contrasts emotion processing induced an increase of the activity as compared to neutral, while no significant deactivation patterns were found. Subsequently, we analysed in detail the dynamics of activation over time averaging the instantaneous images during the time segment significative different**.** The results are reported in Table 3.

Tab 2
Tab 3

Disgust compared to the neutral largely activated the frontal regions with a prevalence in the left side, in particular the bilateral superior frontal gyrus and at a lesser extent the left middle gyrus, the bilateral inferior frontal gyrus, and the left orbitofrontal cortex. In addition, disgust activated the limbic structures, such as the right ACC – BA 32 and 24 - and the left parahippocampal cortex, the region of parietal lobe corresponding to the secondary somatosensorial cortex, and the fusiform gyrus. In the time segment (250 ms and 285 ms) in which the largest response was observed, disgust was also associated with the insular activation (BA 13).
Happiness induced a significant left activation in BA 9 (middle frontal gyrus) and the right activation of the orbitofrontal cortex (BA 47 and 45), that are more extended as respect to the disgust. In the time frames (265 ms and 414 ms), happiness processing was observed to increased the neural activity specifically over the frontal areas. At the limbic level, happiness intensely activated the right cingulate cortex (BA 32 and 23), the left insula and the uncus (BA38). Interestingly, happiness induced a large activity in the occipital structures that form the associative visual systems, including the lingual gyrus (BA18), the cuneus and the precuneus, the middle and superior occipital gyrus (BA19), but not the fusiform gyrus (BA37).
Fear was associated with specific increases of the right-sided limbic activation, including a large part of the cingulate cortex (BA 23, 31, 32), the insula and the hippocampus, whereas it showed a restricted frontal activation (bilateral BA8 and left BA6) as compared with the other emotions. In the time segment (234 ms and 242 ms), fear was characterized by an increased activity that specifically involve the right hemisphere, in particular over the pre-motor cortex (BA6), the temporal regions (BA21, middle and superior temporal gyrus), and the inferior occipital area, including the precuneus (BA19).
Sadness showed a specific and vast activation of the left superior frontal gyrus (BA8), and, at a limbic level, of the right posterior cingulate (BA30 and 31). This emotion intensely and broadly activated the right premotor cortex (BA6) as well, the left insula (BA13), and some structures of the associative visual systems, such as the lingual gyrus and the inferior occipital gyrus (BA18), the precuneus (BA19). In the time window in which the neural response to sadness stimuli highly differ as respect with the neutral a specific increase of frontal activity occurred, involving the right paracentral lobule (BA31) and the left superior frontal gyrus (BA8) and the premotor cortex (BA6) compared to the neutral condition showed significant activation in the right frontal lobe and an activation of the left posterior cingulate.

Fig. 2 and 3

The analysis of the signal onsets and duration allow a better understanding of differences and similarities in the dynamics of activation of the emotion-related neural responses. First, all emotions did not elicit significant onset times earlier than 180 ms after stimulus: sadness produced the earliest, quite long, response, whereas onset times for all other emotions were quite similar around 250 ms. Happiness and sadness showed late onset times (414-418 and 414-500, respectively); in particular, sadness was associated with the longest late segment.
Investigating self-generated emotions during the presentation of facial expression, Esslen et al. (2006) found earlier effects (70 ms) than ours, more numerous and longer. These differences may be attributed to the stimulus material: faces are simple stimuli with an high emotional value for the social species as the human beings, representing an evolutionary-relevant information that may be detected and processed more rapidly than complex scenarios in which the emotional cues have to be extracted from the context.
Considering the LORETA images corresponding to the time segments significant information could be achieved about how the activity in different brain areas changed over time in relation to the emotional stimuli categories.
Disgust was associated with a time segment about 250 ms in which there was an increase of activity in the left ventral anterior cingulate (BA32), in the right premotor cortex, the left PFC (BA10) and the right orbital PFC (BA47), in the bilateral visual cortical areas, including the inferior precuneus (BA19) and the fusiform gyrus (BA37 and BA20); in the successive significant segment there was a large activation in the right PFC (BA9) and, with minor extent, in the left PFC (BA10); in both the time segments, the somato-sensory cortical areas were activated.
Happiness showed a quite opposite pattern, in which the early activation occurred predominantly in the right PFC (and not in the visual areas), and the late activation involved the left PFC and the temporal areas. These results suggest that disgust stimuli could be processed by an early recruitment of the visual resources, and then the information would be projected to the frontal areas, especially on the right hemisphere. Differently, happiness stimuli may be first processed by the right frontal hemisphere and then by the left frontal hemisphere.
Fear showed a pattern quite similar to disgust, with early posterior activation (including visual areas and especially, the temporal cortex), even though there was not a clear frontal processing in the late segment.
The pattern associated with disgusting and threatening stimuli are consistent with the hypothesis that highly arousing and evolutionary salient emotional cues, activate firstly the sensory cortices for the rapid response and then the frontal for a more complete appraisal.

Conclusion

Our findings confirm the hypothesis of a distinct neural circuitry and time behaviour, at least for the different emotion we have investigated. These results, however, must be considered just explorative because spatial undersampling (due to the limited number of electrodes), could be a potential source of imprecision. However, praxis has proved that recording at the 19 standard electrode sites produces reproducible and reliable results in localizing the sources of electric fields (Thatcher et al. 2005). Serial investigation of anatomically known sources with a growing number of electrodes disclosed that LORETA analysis resulted in very similar localization of the generators with 19 and 46 electrodes provided that they are evenly distributed (Michel et al. 2004), as in our study.
Our results are in agreement with the findings of Esslen and collegues (2004), confirming the validity of LORETA for low resolution localization (Pasqual-Marqui and Lehman 1994). Nevertheless, some differences emerged as well. Considering the whole time course of the neural response associated with the observation of stimuli, we found that some areas were shared by all the emotions, and other responded to specific basic emotions. In particular, the present study revealed a large bilateral involvement of the PFC for all emotions, consistent with the findings of Esslen et al. (2004), who argued that the frontal activation may be due to the specific task demand for the PFC role in attentive and memory processes. However, our results showed that PFC was activated also in

a passive viewing task suggesting its independency on task. Furthermore we found that distinct aspect of PFC were involved in processing specific categories of emotional stimuli.
This is consistent with previous findings sustaining that the prefrontal cortex plays a leading role for processing emotions, regardless their specific type (Miller et al. 2001). Finally, these results on the role of the PFC confirm the evidence found in the meta analysis of Phan et al. (2002). Interestingly all emotions activated the premotor area (BA6), suggesting that this region could be involved in emotional network, probably for mediating the component related to the action tendency predisposed by emotion (Frijda 1986). The involvement of the premotor area it is interesting for two aspect. First, research evidenced that the BA6 and BA44 share many functional and histological properties of the macaque premotor cortex the so called "mirror system". Second, subjects with autism spectrum disorder (ASD) typically lack the ability to grasp the emotional dimension and a. biological hypotheses is that this problem is due to the impaired functioning of mirror neuron system (Dapretto et al., 2006). The results support this idea**.**
The time-restricted segments demonstrate that representation of emotion is not continually present in brain work. We have found different time course of the basic emotion respect to the results obtained using emotional face stimuli. Probably, this is because the induction stimuli are different in one case there are emotional face a recognition task in our experiment we induced emotional state using stimuli and this is more ecological and natural. Then it is possible to consider the time course of the emotional experience as a marker of the different basic emotion.
In conclusion, we can consider these results, with the due limitations, a further support for the basic emotion perspective; our results are in agreement with the idea of Damasio et al. (2000) that each emotions has its particular feeling based on specific change in the body regulated by several cortical and subcortical area that control the state of the organism.

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	VALENCE		AROUSAL	
	means	Sd	means	sd
Happiness	7,2805	1,6625	5,051	2,21
Sadness	2,6475	1,525	4,875	2,1
Disgust	3,1425	1,681	5,1535	2,2515
Fear	2,951	1,7215	6,46	2,139

Table 1. Mean and standard deviation of valence and arousal of the different emotional stimuli

Table 2. Whole time course of the different emotion (BA=brodman area) in Talairach coordinate

Disgust						Happy						Fear						Sadness					
Time (ms)	x	y	z	BA	Anat	Time (ms)	x	y	z	BA	Anat	Time (ms)	x	y	z	BA	Anat	Time (ms)	x	y	z	BA	Anat
70-500	-3	58	24	**9**	Sup PFC	70-500	-10	31	19	**32**	ACC	70-500	-3	-23	28	**23**	PCC	70-500	11	26	58	**6**	Sup PFC
	-17	58	17	**10**	Sup PFC		11	26	58	**6**	Sup PFC		4	-23	28	**23**	PCC		-3	19	52	**8**	Sup PFC
	-24	44	12	**10**	Med PFC		-3	26	51	**8**	Sup PFC		4	-23	34	**31**	PCC		-3	26	51	**8**	Sup PFC
	-24	36	-13	**11**	Mid PFC		-38	-4	8	**13**	Insula		-58	-29	41	**2**	Postcentr		11	-36	41	**31**	PCC
	-24	36	-19	**11**	Inf PFC		-31	-11	1	**13**	Insula		-3	31	25	**32**	ACC		25	-86	-7	**18**	Inf Occip
	-31	36	-13	**11**	Mid PFC		-51	-3	27	**6**	Precentr		-17	39	44	**8**	Sup PFC		-58	-22	41	**3**	Postcentr
	-38	37	6	**46**	Inf PFC		-38	-25	-21	**20**	Fusiform		25	25	38	**8**	Mid PFC		-24	12	45	**8**	Sup PFC
	-58	-3	27	**6**	Precentr		-24	38	31	**9**	Mid PFC		52	-37	22	**13**	Insula		18	-84	37	**19**	Precun
	11	12	39	**32**	ACC		-24	32	32	**9**	Mid PFC		-17	19	58	**6**	Sup PFC		25	-57	23	**39**	SupTemp
	18	33	51	**8**	Sup PFC		-24	25	32	**9**	Mid PFC		32	-38	-3		Hippoc		18	-70	30	**31**	Precun
	11	19	58	**6**	Sup PFC		18	16	-18	**47**	Inf PFC		32	-70	30	**19**	Precun		25	-65	11	**30**	PCC
	-24	12	52	**6**	Sup PFC		52	24	13	**45**	Inf PFC		32	-64	30	**39**	Mid Temp						
	-38	-28	54	**3**	Postcentr		25	18	39	**8**	Mid PFC												
	52	24	19	**45**	Inf PFC		-58	-36	41	**40**	Inf Par												
	25	-41	67	**5**	Postcentr		-38	-15	40	**4**	Precentr												
	11	-35	48	**5**	Paracentr		32	30	-1	**47**	Inf PFC												
	-31	-32	-15	**36**	Parahipp		-24	-79	-7	**18**	Lingual												
	-31	-39	-15	**20**	Fusiform		25	8	-29	**38**	Uncus												
							-38	-77	37	**19**	Precun												
							4	-30	28	**23**	PCC												
							-31	-77	24	**19**	Mid Occip												
							-31	-84	24	**19**	Sup Occip												
							-38	-84	24	**19**	Sup Occip												
							11	-36	41	**31**	ACC												
							-3	-91	25	**19**	Cuneus												
							25	-48	68	**7**	Postcentr												
							52	-36	35	**40**	Inf Par												

Disgust						Happy						Fear						Sadness					
Time (ms)	x	y	z	BA	Anat	Time (ms)	x	y	z	BA	Anat	Time (ms)	x	y	z	BA	Anat	Time (ms)	x	y	z	BA	Anat
250- 257	-10	43	-7	**32**	ACC	265-273	4	58	24	**9**	Sup PFC	230- 234	66	-31	9	**22**	Sup Temp	179-204	-51	-2	33	**6**	Precentr
	-17	50	-19	**11**	Sup PFC		4	45	18	**9**	Med PFC		52	-72	-1	**19**	Inf Temp		-58	5	33	**6**	Precentr
	-24	58	17	**10**	Sup PFC		11	45	18	**9**	Med PFC		52	-65	-2	**19**	Inf Temp		-51	-10	14	**43**	Precentr
	-24	44	12	**10**	Med PFC		-17	19	58	**6**	Sup PFC		52	37	6	**45**	Inf PFC		-51	-18	-4	**22**	Sup Temp
	32	-70	37	**19**	Precun								52	37	-7	**47**	Inf PFC		-24	12	45	**8**	Sup PFC
	46	31	19	**46**	Mid PFC	414-418	-51	-12	-22	**20**	Inf Temp		39	31	12	**46**	Inf PFC		-58	-25	-21	**20**	Inf Temp
	59	-3	27	**4**	Precentr		-38	-11	-5	**21**	Sub-Gyral		52	10	13	**44**	Inf PFC		25	-48	68	**7**	Postcentr
	59	4	14	**6**	Precentr		-51	-4	-11	**21**	Mid Temp		46	19	45	**8**	Mid PFC		-10	-99	-6	**18**	Lingual
	46	-4	8	**6**	Precentr		52	24	6	**45**	Inf PFC		46	12	45	**6**	Mid PFC		11	-86	-7	**18**	Lingual
	32	-48	61	**7**	Sup Par		25	-86	-7	**18**	Inf Occip		-17	39	44	**8**	Sup PFC						
	39	-59	-8	**37**	Fusiform		-38	-4	8	**13**	Insula		-10	56	-20	**11**	Orbital	414-500	4	-29	47	**31**	Paracentr
	-31	-39	-15	**20**	Fusiform		18	29	-18	**47**	Inf PFC		25	-8	53	**6**	Precentr		-10	26	58	**6**	Sup PFC
	-58	-29	41	**2**	Postcentr		-10	44	12	**10**	Med PFC		25	-8	59	**6**	Mid PFC						
	32	-45	-3	**37**	Fusiform		-3	58	17	**10**	Med PFC		-58	-29	41	**2**	Postcentr						
	-58	5	33	**6**	Precentr		-24	44	12	**10**	Med PFC		-3	-28	54	**6**	Paracentr						
	-51	-2	33	**6**	Precentr		-58	-35	48	**40**	Inf Par		4	-28	54	**6**	Paracentr						
	-17	-38	3	**30**	Parahipp		-24	58	17	**10**	Sup PFC		-3	-28	60	**6**	Med PFC						
	4	39	44	**8**	Sup PFC		-31	30	-1	**47**	Inf PFC		-38	-18	-16	**20**	Sub-Gyral						
							-38	29	-12	**47**	Inf PFC		-24	-25	-21	**35**	Parahipp						
285- 290	11	-62	56	**7**	Sup Par		25	-65	11	**30**	PCC		32	-38	-3		Hippoc						
	66	-31	9	**22**	Sup Temp		-51	-2	46	**6**	Precentr		-51	-15	53	**3**	Postcentr						
	66	-24	9	**42**	Sup Temp								-31	23	0	**13**	Insula						
	66	-3	14	**4**	Precentr								-31	15	-29	**38**	Sup Temp						
	59	-50	36	**40**	Supramarg								-31	15	-35	**38**	Sup Temp						
	18	46	37	**9**	Sup PFC								-38	15	-29	**38**	Sup Temp						
	18	39	38	**9**	Sup PFC								-17	-99	-6	**17**	Lingual						
	39	5	33	**9**	Precentr								-10	-99	0	**17**	Cuneus						
	39	11	26	**9**	Mid PFC								-17	-99	0	**18**	Cuneus						
	46	4	27	**9**	Inf PFC								-24	-99	0	**18**	Cuneus						
	39	4	27	**9**	Inf PFC								-10	-99	-6	**18**	Lingual						
	46	11	33	**9**	Mid PFC								-24	-99	6	**18**	Mid Occip						
	39	11	33	**9**	Precentr								-3	-91	25	**19**	Cuneus						
	46	5	33	**9**	Inf PFC								11	-85	5	**17**	Lingual						
	52	25	32	**9**	Mid PFC								-24	-91	25	**19**	Cuneus						
	-31	-24	9	**13**	Insula								-24	-91	18	**18**	Mid Occip						
	25	-8	59	**6**	Mid PFC								25	-65	11	**30**	PCC						
	-24	51	18	**10**	Mid PFC																		
	-24	44	12	**10**	Med PFC							242-250	66	-3	20	**6**	Precentr						
	-17	58	17	**10**	Sup PFC								32	-70	30	**19**	Precun						
	-24	58	17	**10**	Sup PFC								25	-8	59	**6**	Mid PFC						
	-10	59	30	**9**	Sup PFC								25	-76	43	**19**	Precun						
													66	-11	-10	**21**	Mid Temp						
													66	-11	1	**21**	Sup Temp						
													46	-8	53	**6**	Precentr						
													39	-79	-7	**19**	Inf Occip						
													46	-9	34	**6**	Precentr						

Table 3. Time course of the different emotion in different time segment (BA=brodman area) in Talairach coordinate

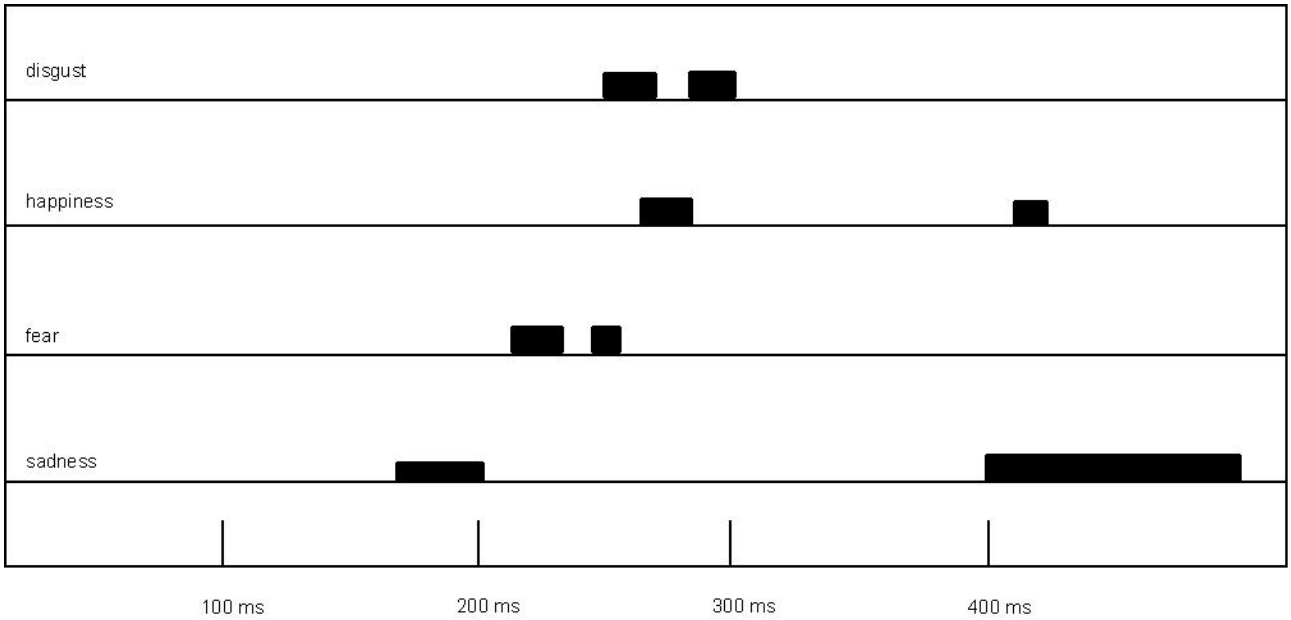

Figure 1. Time segments of significant differences for each condition compared to the neutral condition.

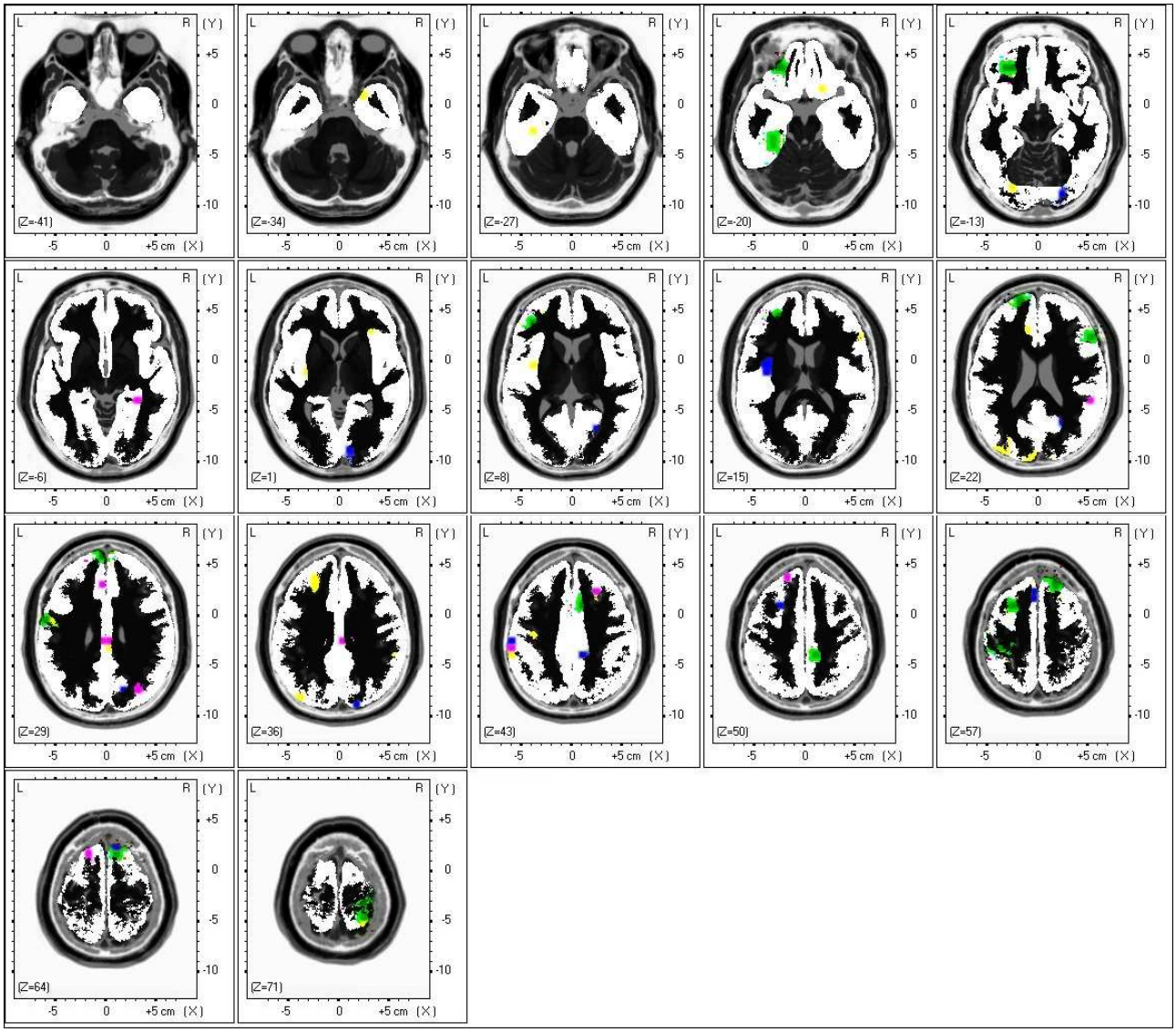

Figure 2 Slices of the brain area activated in the different condition: disgust (green), happiness (yellow), fear (pink), sadness (blue).

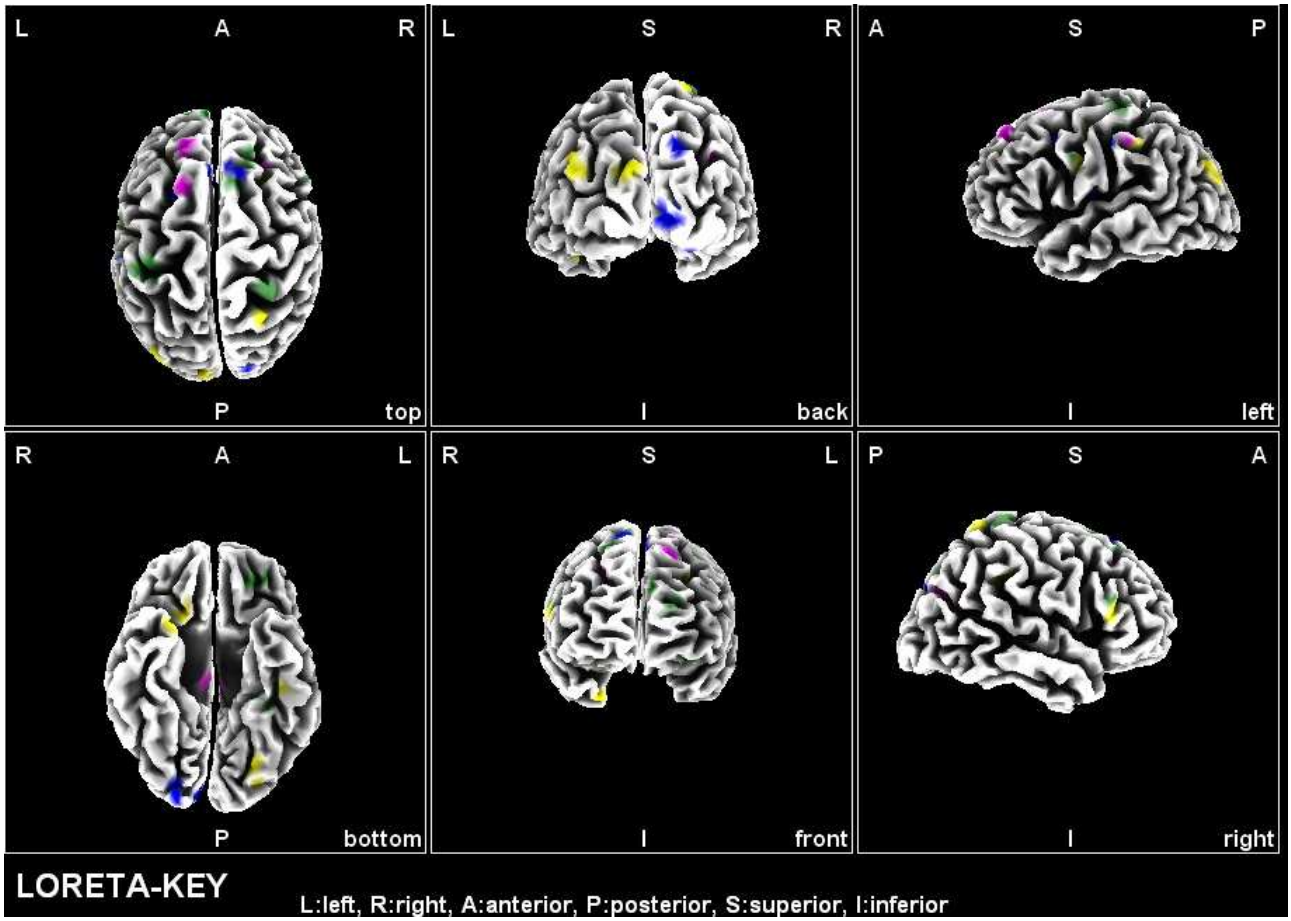

Figure 3 Ortoview of the brain area activated in the different condition: disgust (green), happiness (yellow), fear (pink), sadness (blue).