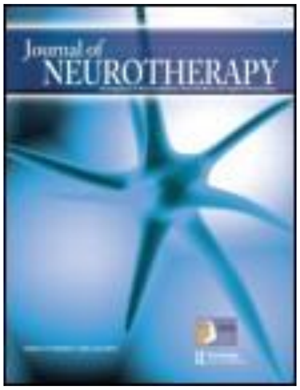

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ENCODING OF EMOTIONAL FACIAL EXPRESSIONS IN DIRECT AND INCIDENTAL TASKS: AN EVENT-RELATED POTENTIALS N200 EFFECT

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Emotional face encoding processes in 2 types of tasks (direct and incidental) were explored in the current research through electroencephalographic (ERPs) and behavioral (response) measures. In Experiment 1 (incidental task) ERP correlates of 21 subjects were recorded when they viewed emotional (anger, sadness and happiness) or neutral facial stimuli. An emotion-specific cortical variation was found, a negative deflection at about 200 ms poststimulus (N2 effect). This effect was sensitive to the perceived emotional value of faces, since it differentiated negative high arousal (i.e., anger) from low arousal (i.e., sadness) or positive (happiness) emotions. Moreover, a specific cortical site (parietal) was activated by emotional faces but not by neutral faces. In Experiment 2 (20 subjects) a direct encoding task (emotion comprehension) was provided. We explored whether encoding for emotional faces relies on a single neural system irrespective of the task (incidental or direct), or whether it is supported by multiple, task-specific systems. The same difference previously observed between emotions, as a function of arousal and valence, was found in the direct condition. Nevertheless, we found differences in the cortical distribution (parietal for the incidental task; central and parietal for direct task) and lateralization (right-distribution for the negative emotions in the direct task) of the N200 on the scalp due to different types of task. The cognitive significance of these ERP variations is discussed.

INTRODUCTION

We investigated the time course of emotional face comprehension elicited by the presentation of facial stimuli during the encoding process, using event-related potentials (ERPs) and behavioral (response) measures. The analysis of the effect of type of task, direct versus incidental, on encoding was the second main aim of this study.

Since certain endogenous ERP components seem to be highly sensitive to specific changes in cognitive states, the ERP procedure allows an analysis of the functional differences in cognition by means of waveform variations (Rugg & Coles, 1995). From this perspective, evidence that emotional faces elicit specific patterns of brain activity could be construed as support for the claim that a dedicated cognitive process exists. An increasing number of studies have analyzed the cognitive and neuropsychological features of face comprehension (Posamentier & Abdi, 2003; Russell, 1994). Specifically, PET studies (Bernstein, Bieg, Siegenthaler, & Grady, 2002; Haxby, Hoffman, & Gobbini, 2000), fMRI (Adolphs, Tranel, & Damasio, 1998; Grelotti, Gauthier, & Schultz, 2002; Kanwisher, McDermott, & Chun, 1997) and ERP measures (Balconi & Pozzoli, 2005; Eimer & McCarthy, 1999; Herrmann et al., 2002; Krolak-Salmon, Fischer, Vighetto, & Maugiere, 2001; Streit, Wölwer, Brinkmeyer, Ihl, & Gaebel, 2000) have underlined the brain specificity of emotion encoding.

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The existence of a specific process to encode emotional features has been well documented by the cognitive model of face processing proposed by Bruce and Young (1986, 1998). This model proposes that there are almost seven distinct types of information that can be derived from a face, such as structural, expression, and identity information. These types of information, which differ in terms of cognitive and functional subprocesses, are represented as ''codes.'' Structural and emotional features of the face are processed independently (Eimer, Holmes, & McGlone, 2003), and ERPs show the functional specificity of brain mechanisms responsible for face processing respectively for structural (N170 effect; Caldara et al., 2003; Eimer, 2000; Olivares, Iglesias, & Bobes, 1998) and emotional type comprehension (N200 effect; Posamentier & Abdi, 2003). ERP studies of faces have shown a classical N170 effect due to structural features of faces: The neural correlates for detecting a face were larger than for many others stimuli, including houses, cars, or eyes (Bentin, Allison, Puce, Perz, & McCarthy, 1996; Bentin & Deouell, 2000; Eimer, 2000; Heisz, Watter, & Shedden, 2006; Rossion et al., 2000), and this ERP component is not affected by face familiarity (Jemel, George, Chaby, Fiori, & Renault, 1999). Many studies have also found no modulation of N170 as a function of emotional content of facial expressions (Holmes, Vuilleumier, & Eimer, 2003; Holmes, Winston, & Eimer, 2005; Puce, Allison, & McCarthy, 1999).

There is evidence that emotional processes can be differentiated in earlier time windows (Balconi & Pozzoli, 2008; Holmes et al., 2003; Streit et al., 2000), and that ERP variations were specific for emotional content of expressions, such as a negative variation during 200–300 ms (Balconi & Pozzoli, 2003a, 2003b; Balconi, Brambilla, & Falbo 2009; Krolak-Salmon et al., 2001; Marinkovic & Halgren 1998; Streit et al., 2000; Vanderploeg, Brown, & Marsh, 1987) and a positive deflection at about 300 ms (Morita, Morita, Masashi, Waseda, & Maeda, 2001). Specifically, recent ERP studies observed a posterior negativity, reflecting facilitated processing of emotional stimuli (Schupp, Junghöfer, Weike, & Hamm, 2003). In fact, it was demonstrated that emotional faces (fear and happiness) elicited a larger negativity at approximately 270 ms than neutral faces over the posterior temporal areas (Sato, Takanori, Sakiko, & Michikazu, 2001). Moreover, Vanderploeg et al. (1987) and Marinkovic and Halgren (1998) reported that the visual presentation of emotional-facial expressions elicited more negative amplitudes during 230–350 ms than neutrally rated stimuli and that this ERP effect is more distributed at lateral occipito-temporal site. Another study investigated the influence of facial expressions and blurred faces on ERP measures, without any differences between conditions (emotional vs. blurred faces) at 120 and 170 ms after stimulus onset, but significant differences in amplitude between 180 and 300 ms (Streit et al., 2000). Nevertheless, in spite of these consistent results, other studies found that N200 did not supply evidence in favor of differential processing for facial expressions (Carretié & Iglesias, 1995; Hermann et al., 2002), and this ERP effect was considered as independent from facial expression analysis. In Carretié and Iglesias (1995), the latency of this deflection was clearly anticipated in comparison with other 250–350 ms negative deflections previously found. For this reason we propose that it may be analogous of the structural marker (N170 ERP effect), not sensitive to emotional features of faces.

N200 Effect and Facial Expressions of Emotion

Thus, two theoretical positions were proposed to explain the cognitive significance of this early negative variation. The first interpretation proposed that the N200 could be a ''cognitive marker'' of the complexity and the salience of the facial stimulus (Carretié & Iglesias, 1995). Nevertheless, some authors stated that this position is inconsistent with a large part of the experimental evidence (Marinkovic & Halgren, 1998; Sato et al., 2001; Streit et al., 2000). A second position pointed out the emotional specificity of the N200, as it is thought to be an index of the emotional encoding of facial stimuli, and it may signal different ''emotional values'' of facial expressions (Balconi & Pozzoli, 2003b; Posamentier & Abdi, 2003). Thus, some fundamental questions remain to be answered, taking into account the divergence between previous research results. First, the cognitive nature of this ERP variation must be clarified, considering the specificity of the N200 for emotional facial expression encoding. The comparison of facial expressions with a neutral condition (neutral facial expression) becomes crucial in order to characterize the emotional significance of this early peak variation. Moreover, spatial localization of the N200 effect is a point to be elucidated. Previous research found a more posterior distribution of the peak, and specifically it was localized in the temporo-occipital sites of the scalp (Sato et al., 2001). Nevertheless, some studies have found a different cortical distribution of the peak, such as the central or anterior localization (Streit et al., 2000). Therefore, we intend to analyze the ERP profile, in terms of brain distribution of the N200, as evidence of the existence of a cortical-specific site for emotion encoding.

Types of Emotions: Hedonic Value and Arousal Effect

A second main question of the current research is about the effect of type of emotions on ERP correlates. Recent neuropsychological and neuroimaging data have been interpreted as indicating that emotional perception, and specifically perception of facial expressions, is organized in a modular fashion, with distinct neural circuitry subserving individual emotions (Adolphs, Tranel, & Damasio, 2003; Balconi, 2006; Batty & Taylor, 2003; Calder, Keane, Manes, Anton, & Young, 2000). However, few studies have examined the range of ''basic'' emotions or distinguished possible differential activation as a function of the emotions. Some of them analyzed face-specific brain potentials (Eimer, 2000; Eimer & McCarthy, 1999), but it was considered only a limited number of emotions, usually comparing one positive and one negative emotion, such as sadness and happiness (Herrmann et al., 2002). As previously revealed, the human brain differentiates between pleasant and unpleasant stimuli earlier than previously thought and both hemispheres are able to perform this differentiation (Pizzagalli, Regard & Lehmann, 1999). In addition, studies on impairment of facial-expression recognition suggested category-specific deficits in comprehending the emotional expressions (i.e., fear and not happiness) after brain injury of the amygdala (Adolphs et al., 1998; Davidson, 2001; Young, Hellawel, Van de Wal, & Johnson, 1996). Moreover, findings of previous research have pointed out a modulation of late deflections of ERPs as a function of ''motivational significance'' (P. J. Lang, Bradley, & Cuthbert, 1997). Specifically, greater magnitude of ERP deflection was found in response to emotionally salient stimuli (unpleasant compared to neutral; Palomba, Angrilli, & Mini, 1997; Schupp et al., 2000). This effect has been theoretically related to motivated attention, in which motivationally relevant stimuli naturally arouse and direct attentional resources (Hamm, Schupp, & Weike, 2003; Keil et al., 2002; P. J. Lang et al., 1997). So how can we explain this effect of motivation on ERPs? As suggested by the ''functional model,'' each emotional expression represents the subject's response to a particular kind of significant event—a particular kind of harm or benefit—that motivates coping activity (Frjida, 1994; Hamm et al., 2003; Moffat & Frijda, 2000). The implications of the event for the well-being of the organism took central stage, involving primary appraisal, according to Lazarus (1999).

Thus, a second main question of the present research is whether the motivational value of facial expressions could have an effect on stimulus elaboration, and whether it could be revealed by ERP variations. As suggested by the ''functional model,'' we proposed that subjects might be more emotionally involved by a high-threatening negative expression (i.e., anger) than a low-threatening positive emotion (happiness) and that they might have a more intense emotional reaction while viewing a negative high-arousing (highly salient) than a negative low-arousing emotion (S. F. Lang, Nelson, & Collins, 1990; Wild, Erb, & Bartels, 2001). Consequently, the level of attention may change as a function of the subjective response to face stimulus, and ERP measure can be a significant marker of the increased involvement and attention addressed to the stimulus. Thus, we hypothesize that significant differences have to be found between the two categories of high/low arousal and positive/negative emotions.

Task Effect

A consistent difference in face encoding processes was observed based on type of task (direct versus incidental task; Critchley et al., 2000; Eimer et al., 2003; Gorno-Tempini, Pradelli, Serafini, Baraldi, & Porro, 2001; Rossion et al., 1999; Winston, O'Doherty, & Dolan, 2003). Specifically, consistent variations were observed between an explicit and an implicit task, where the first includes the request of a direct elaboration of a specific feature of the stimulus (i.e., emotion) and the second does not require a direct encoding but only an incidental processing (Critchley et al., 2000). A task effect was observed for words, objects, and faces. Recent evidence demonstrated that brain processes involved in the detection and analysis of facial expression require focal attention (Eimer et al., 2003). In some cases, a significant effect of face encoding was found on several cortical and subcortical regions, modulated by task type and by facial expressions (Adolphs, 2002; Calder, Lawrence, & Young, 2001). Nevertheless, whereas some lesion studies are limited to tasks requiring explicit recognition of facial emotion, and most imaging studies have relied upon incidental emotional processing, a few studies have used event-related designs that allow a fine control of spatio-temporal variations of neural activation during the execution of the cognitive task. In addition, the stimulus material used included only a few emotions (normally two emotional expressions; Gorno-Tempini et al., 2001), which does not make explicable the effect of emotions in an ample range of types. Moreover, previous studies did not focus on the specific N200 effect but studied the earlier N170 component. We did not explore directly the effect of attention on face decoding, but we opted for a detailed analysis of type of task (direct vs. incidental).

Objectives and Hypotheses

To summarize our main objectives, we aimed at investigating the encoding process of emotional faces, taking into considerations these main points:

1. Providing an accurate description of encoding process of emotional faces, through ERP measures, and specifically the N200 effect. The specificity of N200 for emotion was tested on a vast range of facial expression (Experiment 1).
2. Exploring the effect of emotional expression types on ERPs, as a function of their ''motivational significance'' for the subjects. Specifically we intended to verify the relationship between the emotional evaluation (in terms of arousal and hedonic value) and the N200 amplitude modification (Experiment 1).
3. Assessing the effect of task on neural responses to facial expressions when multiple emotions are considered. We reasoned that, in contrast to the incidental encoding condition, the direct encoding required participants to attend more closely to emotional features of the stimulus, and to engage in more evaluative operations in comprehending faces. Although these operations require greater demands and effort on attention, they can guarantee a better and deeper processing (Experiment 2).
4. Revealing cortical wave variations in terms of wave morphology or wave distribution that might indicate that there exists a qualitative rather than a quantitative difference in the neural activity underlying the ERP effects in the two tasks (Experiment 2).
5. Verifying the resemblance of N200 ERP effect with respect of emotional type differences in both indirect and direct conditions. In fact we expected that ERP sensitivity to emotional content (positive vs. negative

hedonic value and high vs. low arousal) will be similar for direct and incidental decoding (Experiment 1 and 2 comparisons).

EXPERIMENT 1

Method

Participants. Twenty-one (11 men, age range = 21–25; $M = 23.30$, $SD = 0.56$) psychology students at the Catholic University of Milan took part in the research. They all were right-handed, with normal or corrected-to-normal visual acuity, and all denied any history of neurological or mental abnormalities. They were recruited for a cognitive task of stimulus encoding but were not aware that the investigation of emotional variable was the real purpose of the experiment. The subjects gave their overt consent to participate to the experiment (they were neither paid nor received course credits).

Materials and Procedure. Stimulus materials were taken from the set of pictures of Ekman and Friesen (1976), thus previously tested for the homogeneity of the encoded expressions and the intensity of each expression. They were black-and-white pictures (11 × 15 cm) of a young male or female actor (opportunely randomized across the emotions), presenting respectively a happy, sad, angry, or neutral face (20 unique faces, the same used across the emotions). The neutral faces did not present a specific emotional expression. The items are identical in terms of lighting and angle. Pictures were presented in a random order in the center of a computer monitor placed approximately 80 cm from the subject, with a visual horizontal angle of 4° and a vertical angle of 6° (STIM 4.2 software). An interstimulus fixation point was projected at the center of the screen (a white point on a black background). Each stimulus was presented for 500 ms on the monitor with an interstimulus interval of 1,500 ms. Every type of emotional expression was presented 20 times, resulting in a total of 80 trials. After a brief introduction to the laboratory, the subjects were seated in sound-attenuated, electrically shielded room, and they were asked not to blink during the task. The subject was told to observe the stimuli carefully for a successive recognition process, but they were not asked to judge the emotional content of faces. In this experiment we used an incidental task (gender decision task). A motor response (by stimpad) to the features of the stimulus was required (button response was counterbalanced). Prior to recording ERPs, the subject was familiarized with the overall procedure (training session), where every subject saw in a random order, all the emotional stimuli presented in the successive experimental session (a block of 16 trials, each type of expression repeated four times).

Stimulus Evaluation Task. All the subjects were subsequently asked (postexperimental phase) to analyze the facial expressions and to express the degree of their own emotional involvement for each emotion. In fact, to rate the emotional value of face and the emotional reaction to a single expression, the subjects were asked to identify each expression (categorization of face), to evaluate its pertinence (category pertinence) and hedonic value, and to quantify the strength of experienced emotions (high vs. low arousal; Balconi & Pozzoli, 2003b; P. J. Lang, Greenwald, Bradley, & Hamm, 1993). They correctly recognized the emotional value of the stimuli (with correct identification 94.58%; for neutral expression the definition was ''no emotion''), and they evaluated each expression as highly pertinent with its emotional category (Likert scale 5 points; respectively for happiness $M = 4.43$, $SD = 0.50$; sadness $M = 4.20$, $SD = 0.33$; and neutral $M = 4.11$, $SD = 0.82$). The hedonic value of facial expressions was tested. Specifically angry ($M = 4.61$, $SD = 0.44$) and sad ($M = 4.21$, $SD = 0.52$) faces were considered negative emotions, whereas happiness was evaluated as a positive expression ($M = 1.25$, $SD = 0.70$). Neutral expressions were considered not hedonically significant ($M = 2.75$, $SD = 0.38$). The significance of the differences between the emotions was tested by an univariate analysis of variance (ANOVA); for emotion, $F(3, 20) = 16.78$, $p = .001$, $\eta^2 = .62$. The planned contrasts showed a significant difference between anger and happiness, $F(1, 20) = 10.87$, $p = .001$, $\eta^2 = .49$, and sadness and happiness, $F(1, 20) = 8.32$, $p = .001$, $\eta^2 = .40$. No other comparison was significant.

Moreover, the subjects evaluated on a Likert-like scale as more emotionally involving the negative high-threatening emotion (anger, $M = 4.55$, $SD = 0.62$) than happiness ($M = 2.15$, $SD = 0.68$), sadness ($M = 2.50$, $SD = 0.37$), and neutral faces ($M = 1.01$, $SD = 0.80$). The statistical significance of the differences between the four facial expressions was tested by an univariate ANOVA (for the main factor of emotion), $F(3, 20) = 13.48$, $p = .001$, $\eta^2 = .52$. An ANOVA for planned contrasts showed different responses between anger and happiness, $F(1, 20) = 9.50$, $p = .001$, $\eta^2 = .43$, and sadness, $F(1, 20) = 7.73$, $p = .001$, $\eta^2 = .36$. Finally, the three expressions differentiated with neutral expression: respectively, anger, $F(1, 20) = 14.10$, $p = .001$, $\eta^2 = .49$; happiness, $F(1, 20) = 9.02$, $p = .001$, $\eta^2 = .40$; and sadness, $F(1, 20) = 10.51$, $p = .001$, $\eta^2 = .46$. Type I errors associated with inhomogeneity of variance were controlled by decreasing the degrees of freedom using the Greenhouse-Geiser epsilon.

Registration and ERP Measures. The EEG was recorded with a 64-channel DC amplifier (*SYNAMPS* system) and acquisition software (NEUROSCAN 4.2) at 32 electrodes (International 10-20 system, Jasper, 1958) with reference electrodes at the mastoids, and mounted in a stretch-Lycra electro-cap (high-density registration). Electroculograms were recorded from electrodes lateral and superior to the left eye. The signal (sampled at 256 Hz) was amplified and processed with a band pass filter from .01 to 50 (off-line) Hz and was recorded in continuous mode. Impedance was controlled and maintained below 5 KΩ. Twelve of the registered sites were considered for the statistical analysis (four central, Fz, Cz, Pz, Oz; eight lateral, F3, F4, T3, T4, P3, P4, O1, O2). An averaged waveform (off-line) was obtained from about 20 artifact-free (trials exceeding 50 μV in amplitude were excluded from the averaging process) individual target stimuli for each type of emotion. The EEG signals were visually scored on a high-resolution computer monitor and portions of the data that contained eye movements, muscle movements, or other source of artifact were removed. The percentage of the rejected epochs was low (5%; the grand average was obtained from no less than 18 epochs for each category). Peak amplitude measurement was quantified relative to 100 ms prestimulus (epoch duration: −100/900 ms).

Results

Component windows were defined based on grand average ERP wave forms across all types of emotion and electrodes. To evaluate differences in ERP response we focused data analysis within the time window 200–300 ms poststimulus. The time-window reference is a common procedure that allowed us to measure the average variation around a peak (Rugg & Coles, 1995). To analyze early ERP effects in face encoding, we focused on this temporal range and we did not consider previous or successive peak variations. First, we decided not to statistically analyze the N170 ERP effect, which was shown to be related to the structural encoding of faces by previous studies, and, on the contrary, we focused on a later deflection, observed in response to emotional content of the faces (Posamentier & Abdi, 2003). The morphological analysis of waves confirmed the existence of a consistent ERP negative deflection from 200–300 ms, whereas some successive (P3) deflections were not systematically present between the subjects. Finally, whereas P300 ERP effect was previously explored in relation with emotional stimulus encoding, it was shown that there was a heterogeneous number of results for the P300.

Two dependent variables, the peak value (calculated from baseline to peak amplitude) and the latency of the peak (the time of emergence of the peak), were entered into four different two-way repeated measure ANOVAs (two applied to peak amplitude and two to peak latency), using the following repeated factors: for the first ANOVA type of Stimuli (4) × Site (4); for the second ANOVA Type (4) × Lateralization (2). The site effect was analyzed by means of four separate electrodes (Fz vs. Cz vs. Pz vs. Oz). To assess lateralization, a lateral electrode factor (F4, T4, P4, O2 vs. F3, T3, P3, O1) was created. Type I errors associated with inhomogeneity of variance were controlled by decreasing the degrees of freedom using the Greenhouse-Geiser epsilon.

The first repeated measure ANOVA applied to the peak amplitude variable showed a significant main effect for type, $F(3, 20) = 23.56$, $p = .001$, $\eta^2 = .58$, and site, $F(3, 20) = 14.56$, $p = .001$, $\eta^2 = .58$. Table 1 shows the mean values for each emotion and electrode sites.

The two-way interactions were not statistically significant. As shown in Figure 1, a peak at 223 ms is observable for all of the emotional expressions.

A successive ANOVA with planned contrasts was applied to type effect. From the analysis it was observed that happiness, sadness, and neutral expressions had a more positive peak than anger (respectively, anger/happiness comparison), $F(1, 20) = 8.06$, $p = .001$, $\eta^2 = .40$; anger/sadness, $F(1, 20) = 11.11$, $p = .001$, $\eta^2 = .53$; anger/neutral, $F(1, 20) = 10.06$, $p = .001$, $\eta^2 = .49$. On the contrary, no differences were revealed between happiness and sadness, but they both were differentiated from the neutral face, as revealed by the comparison happiness/neutral, $F(1, 20) = 8.97$, $p = .001$, $\eta^2 = .43$, and sadness/neutral, $F(1, 20) = 7.18$, $p = .001$, $\eta^2 = .40$. Second, the successive analysis applied to the simple effect of site revealed that the negative deflection was higher at Pz than Fz, $F(1, 20) = 15.67$, $p = .001$, $\eta^2 = .54$, and Cz, $F(1, 20) = 9.40$, $p = .001$, $\eta^2 = .44$, sites. Figure 2 reports the cortical distribution of N200 as a function of the four sites.

A second repeated measure ANOVA was applied to the latency measure. No significant main effect was found, respectively, for type, $F(3, 20) = 1.24$, $p = .42$, $\eta^2 = .13$, and site, $F(3, 20) = 1.04$, $p = .24$, $\eta^2 = .12$, as well as their two- three-way interactions. Therefore, the peak latency was quite similar in each emotion and in all sites of the scalp.

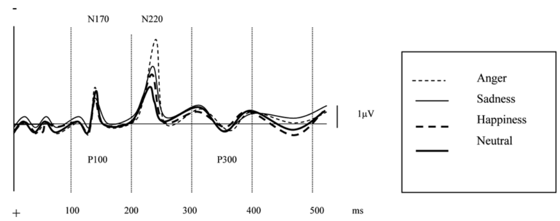

FIGURE 1. Grand averaged waveforms (all electrodes) of N200 for the facial expressions.

The second set of ANOVAs showed significance only for type effect but not for the lateralization effect, respectively, $F(1, 20) = 12.20$, $p = .001$, $\eta^2 = .58$; $F(1, 20) = 1.01$, $p = .32$, $\eta^2 = .11$ (see Table 1). No significant effect was found for latency.

Finally, to compare the relationship between the emotional evaluation and ERP variations, a correlation (bivariate Pearson correlation) was conducted. Specifically, peak amplitude values (*z* scores) for each emotion were compared to the subjects' evaluation. For hedonic evaluation, a positive relationship was observed between evaluation of anger ($r = .543$, $p = .001$), happiness ($r = .563$, $p = .001$), and sadness ($r = .580$, $p = .001$) and peak amplitude (a more negative evaluation for anger and sadness corresponds to an ampler peak; a less negative evaluation for happiness corresponds to a decreased peak amplitude).

TABLE 1. Mean Values of N200 ERP for Each Emotion, Electrode Site, and Side (Incidental Task)

	Electrode sites											
	Fz		Cz		Pz		Oz		Right		Left	
	Amplitude[a]											
	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*
Happiness	2.28	.29	2.30	.64	2.28	.52	2.26	.48	2.18	.37	2.26	.44
Hadness	2.18	.37	2.37	.61	2.49	.80	2.38	.56	2.53	.47	2.12	.69
Anger	2.63	.49	2.50	.33	3.40	.55	2.91	.42	2.78	.22	2.42	.73
Neutral	2.04	.40	2.08	.34	2.26	.43	2.10	.69	2.07	.43	2.03	.44
Total *M*	2.29	.36	2.33	.51	2.50	.58	2.41	.53	2.38	.41	2.24	.53

Note. Amplitude = expressed in μvolt. The values are negative.

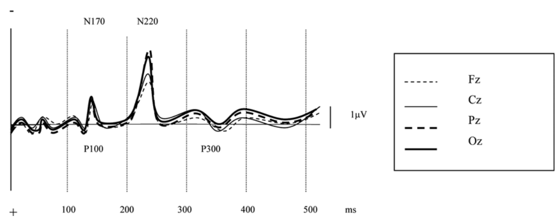

FIGURE 2. Grand averaged waveforms of N200 for the four cortical sites.

For arousal evaluation the correlation showed a significant effect for all the emotion types. Specifically, for anger ($r = .675$, $p = .001$), happiness ($r^2 = .512$, $p = .001$), sadness ($r = .611$, $p = .001$), and neutral ($r = .663$, $p = .001$), a positive relationship was observed between arousal evaluation and peak amplitude. In particular, anger showed an increase in peak amplitude as a function of the increased emotional involvement, as well as happiness, sadness, and neutral peak amplitude decreasing, which was related to reduced involvement.

Discussion

First, the functional significance of N200 ERP effect for emotional face encoding (emotional vs. neutral) and, second, the emotion-discrimination by ERP as a function of the content of facial expressions (''motivational significance'') are discussed. Our data support the view that emotion discrimination occurs with a latency of about 220 ms from stimulus onset, that emotional facial expressions induce greater activation of the parietal areas, and that the N200 deflection is affected by emotional significance of faces (Balconi & Lucchiari, 2005a, 2005b; Sato et al., 2001; Streit et al., 2000).

First, because all of the emotional expressions were differentiated from neutral expressions, N200 can represent an ERP marker of emotional content of the face, and not a generic cue of facial stimulus elaboration. Thus, our data indicate that this component reflects a specific emotional processing: When the emotional content of faces is varied (i.e., emotional or neutral), N200 reacts more to the emotional value of the stimulus. Moreover, the negative variation was heterogeneously distributed on the scalp, and a more parietal distribution was observed. In line with previous studies, our results showed that the posterior sites were revealed as much more involved in emotional facial expression comprehension than neutral stimuli (Deldin, Keller, Gergen, & Gregory, 2000; Sato et al., 2001). Neural networks have been proposed for processing specific facial emotion, with the implicated regions including cortical (mainly occipito-temporal junction) and subcortical structures (amygdala, basal ganglia and insula; Damasio et al., 2000; Gorno-Tempini et al., 2001).

The second main and new result of this research is that the N200 is different among the four facial stimuli in terms of peak amplitude variation. The results allowed us to extend the range of emotions and to explore in detail the functional value of ERPs applied to facial expressions. The different ERP profiles found as a function of the emotional content of the stimulus may indicate the sensitivity of this negative-wave variation to the ''semantic'' value of facial expressions (Jung et al., 2000). A more negative peak is produced by anger than happiness and sadness. By contrast, very similar potentials, with identical latency and amplitude, were observed for happy and sad expressions, differentiated from anger.

In addition, the subjective perceived significance of faces in terms of arousal and hedonic value (high/low arousing expressions; positive/negative value) is important, and this procedure is different from a simple comparison of a priori categorization. The direct relationship between subjective evaluation and ERP variations could suggest a specific effect of face perception on the cognitive response to emotional stimuli. The correlational analysis allowed us to underline the systematic correspondence between a subjects' evaluation in terms of hedonic evaluation of faces, emotional involvement, and ERP variations. Therefore a link is proposed between the perceived arousal and the increasing or decreasing of peak amplitude. These two main parameters seem to affect the ERP profile, related to threatening or unthreatening significance of the emotional expressions. Specifically, it is plausible that negative emotions (like anger) may induce a stronger reaction within the subject than positive emotions (like happiness), with more intense emotional response, and that experienced emotional intensity may increase while viewing a negative high-threatening emotion but decrease while viewing a negative low-threatening emotion (S. F. Lang et al., 1990; Yee & Miller, 1987). This assumption is strengthened by the finding of the behavioral responses of the subject: Anger elicited negative intense feelings, and it is considered as much more negative than sadness, and moreover than happiness, whereas happiness and sadness were less involving. This would suggest that the effect due to emotional arousal should be greater for unpleasant negative stimuli, which were rated as slightly more arousing than less relevant stimuli. Thus, it is plausible that as a function of the threatening power (from higher to lower), emotional expressions are distributed along a heterogeneous space, as well as the subjects' emotional response to them, and this fact is reflected by ERP variation, with an increasing negativity of N200. Such evidence supports the notion that affective processing happens on a broad continuum, as expected by the functional model. In fact, from an evolutionary point of view, negative, relevant emotions appear to be most prominent as a human safeguard (S. F. Lang et al., 1990). Specifically, they facilitate the survival of the species and the immediate and appropriate response to emotionally salient (threat-related) stimuli confers them an ''adaptive'' value (Ellsworth & Scherer, 2003). For example, in regard to anger, we can state that it's related to negative feeling and high attention. This appraisal produces specific physiological and cognitive reactions. On the whole, more threatening negative facial stimuli may evoke greater arousal than positive unthreatening stimuli, and greater peak amplitude may indicate these physiological and cognitive responses to them (Polich & Kok, 1995).

EXPERIMENT 2

Method

Participants. Twenty subjects (12 men, age range = 21–25; $M = 23.15$, $SD = 0.34$; different from those of Experiment 1), students of psychology at the Catholic University of Milan, took part in the research. They all were right-handed and with normal or corrected-to-normal visual acuity, and all denied any history of neurological or mental abnormalities. They gave informed consent and were neither paid nor received course credits.

Materials and Procedure. The same procedure adopted in Experiment 1 was used, as well as the same stimulus material. The main procedural variation of the present experiment was the experimental task. To assess the neural correlates of making judgment concerning the emotional content of faces, our design incorporated a ''direct'' task in which subjects made an emotional judgment concerning each expression (expression recognition; Winston et al., 2003). Prior to recording ERPs, the subjects were familiarized with the overall procedure, where every subject saw in a random order all the emotional stimuli presented in the successive experimental session (16 trials).

Stimulus Evaluation Task. All the subjects were subsequently asked to analyze the facial expressions in a postexperimental phase (for more details, see Experiment 1). The subjects were asked to identify each expression, to evaluate their pertinence and the hedonic value, and to quantify the strength of experienced emotions. They correctly recognized the emotional value of the stimuli (with correct identification of 96.50% and a judgment of ''no emotion'' for neutral face), and evaluated each expression as pertinent (respectively, for anger, $M = 4.61$, $SD = 0.96$; happiness, $M = 4.20$, $SD = 0.82$; sadness, $M = 4.17$, $SD = 0.47$; and neutral, $M = 4.15$, $SD = 0.60$). The hedonic value of facial expressions was tested. Specifically angry ($M = 4.82$, $SD = 0.48$) and sad ($M = 4.47$, $SD = 0.53$) faces were considered negative emotions, whereas happiness was evaluated as a positive expression ($M = 1.19$, $SD = 0.40$). Neutral expressions were considered not hedonically significant ($M = 2.28$, $SD = 0.43$). The significance of the differences between the emotions was tested by an univariate ANOVA: for emotion, $F(3, 20) = 20.45$, $p = .001$, $\eta^2 = .66$. The planned contrasts showed a significant difference between anger and happiness, $F(1, 20) = 12.09$, $p = .001$, $\eta^2 = .56$, and sadness and happiness, $F(1, 20) = 9.87$, $p = .001$, $\eta^2 = .48$. No other comparison was significant. Finally, they evaluated as more emotionally involving the negative emotion of anger ($M = 4.63$, $SD = 0.72$) than happiness ($M = 2.30$, $SD = 62$), sadness ($M = 2.15$, $SD = .83$), and neutral ($M = 1.77$, $SD = 0.61$) stimuli. The univariate ANOVA showed a significant main effect for type of emotion, $F(3, 19) = 14.32$, $p = .001$, $\eta^2 = .53$, and the successive comparison (ANOVA for contrasts) revealed different responses between anger and the other emotions: respectively, happiness, $F(1, 19) = 8.10$, $p = .001$, $\eta^2 = .43$, and sadness. $F(1, 19) = 8.93$, $p = .001$, $\eta^2 = .43$. Neutral expression was differentiated from the other three emotions: respectively, anger, $F(1, 19) = 16.70$, $p = .001$, $\eta^2 = .47$; happiness, $F(1, 19) = 15.32$, $p = .01$, $\eta^2 = .43$; and sadness, $F(1, 19) = 14.25$, $p = .03$, $\eta^2 = .42$.

EEG Registration Parameters. EEG was recorded in the same manner of Experiment 1 (32 electrodes by an electro-cap, international 10-20 system) with acquisition software NEUROSCAN 4.2. Only 4% of the epochs were rejected for artifacts (no less than 19 epochs for each category).

Results

Component windows were defined based on grand average ERP wave forms across all type of emotion and electrodes. The time window 200–300 ms poststimulus was used to analyze peak variations, as the morphological exploration of the wave profiles revealed a peak variation at all analogous to that observed in Experiment 1, within the same time interval. The variables were entered into four two-way repeated measure ANOVAs, using as repeated factors Type of Emotion (4) × Site (4) and Type (4) × Lateralization (2). Table 2 shows the mean values as a function of emotion and electrode sites.

As showed by an ANOVA, type of emotion was significant in distinguishing peak variation, $F(3, 19) = 22.35$, $p = .001$, $\eta^2 = .68$, as well as site, $F(3, 19) = 8.43$, $p = .001$, $\eta^2 = .49$. The contrast analyses revealed differences between anger and happiness, $F(1, 19) = 15.66$, $p = .001$, $\eta^2 = .53$; and anger and sadness, $F(1, 19) = 14.10$, $p = .001$, $\eta^2 = .50$. Moreover, all the emotions were differentiated from the neutral face: for anger, $F(1, 19) = 9.56$, $p = .001$, $\eta^2 = .38$; happiness, $F(1, 19) = 10.16$, $p = .001$, $\eta^2 = .42$; and sadness, $F(1, 19) = 10.45$, $p = .001$, $\eta^2 = .47$. The main effect of site showed a more central (Cz), $F(1, 19) = 14.55$, $p = .001$, $\eta^2 = .53$, and parietal (Pz), $F(1, 19) = 11.24$, $p = .001$, $\eta^2 = .51$, distribution of the peak than anterior (Fz) position. Figure 3 shows the ERP profile as a function of the four cortical sites.

Latency dependent variable was entered in two successive repeated measure ANOVAs. The analysis did not reveal a significant main effect for either type, site or lateralization effects.

The successive set of ANOVAs showed a significant effect for type, $F(3, 19) = 12.56$, $p = .001$, $\eta^2 = .54$, and Type × Lateralization interaction, $F(3, 19) = 9.65$, $p = .001$,

TABLE 2. Mean Values of N220 ERP for Each Emotion, Electrode Site, and Side (Direct Task)

	Electrode sites											
	Fz		Cz		Pz		Oz		Right		Left	
	Amplitude[a]											
	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*
Happiness	2.08	.33	2.49	.69	2.50	.50	2.38	.40	2.24	.28	2.36	.66
Sadness	1.89	.28	2.73	.68	2.68	.53	2.65	.32	2.92	.43	2.45	.73
Anger	2.37	.41	2.90	.62	3.10	.28	2.93	.57	3.21	.23	2.80	.45
Neutral	2.03	.56	2.25	.91	2.26	.30	2.26	.48	2.15	.20	2.06	.39
Total Mean	2.09	.39	2.50	.55	2.65	.42	2.56	.44	2.63	.28	2.40	.55

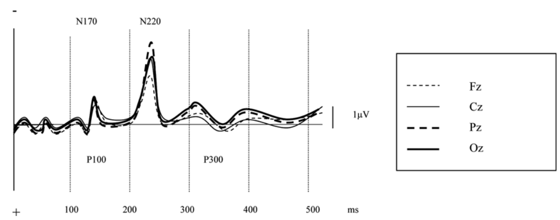

FIGURE 3. Grand averaged waveforms of N200 for the four cortical sites.

$\eta^2 = .43$. Specifically the comparison for Type × Lateralization effect revealed a more right distribution of the peak for the negative expressions of anger, $F(1, 19) = 10.75$, $p = .001$, $\eta^2 = .46$, and sadness, $F(1, 19) = 7.03$, $p = .001$, $\eta^2 = .32$, compared with happiness. The same trend was revealed for the negative emotions of anger, $F(1, 19) = 8.81$, $p = .001$, $\eta^2 = .45$, and sadness, $F(1, 19) = 8.15$, $p = .001$, $\eta^2 = .40$, compared with neutral faces (see Table 2). Figure 4 represents the topographical maps of the scalp for each emotion as a function of the two cortical sides, left and right.

By contrast, no significant effect was found for the latency measures.

Finally, to compare the relationship between the emotional evaluations and ERP variations a Pearson bivariate correlation was conducted. Specifically, peak amplitude values for each emotion were compared to the subjects' evaluation. The correlation showed a significant effect for all the emotion types. It showed a positive relationship between stimulus hedonic evaluation/peak amplitude, because anger ($r = .661$, $p = .001$), sadness ($r = .672$, $p = .001$), and happiness ($r = .523$, $p = .001$) showed significant results (increased peak values for anger and sadness; decreased peak values for happiness). For the arousal

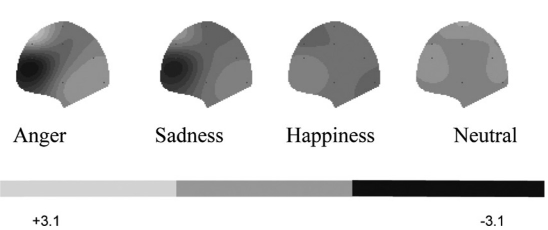

FIGURE 4. Topography of event-related potential maps for each emotion (coronal section, left view).

anger ($r = .620$, $p = .001$), happiness ($r = .582$, $p = .001$), sadness ($r = .532$, $p = .001$), and neutral ($r = .661$, $p = .001$) faces were correlated with peak amplitude. Happiness, sadness, and neutral peak amplitudes decreased proportionally as a function of the lower emotional involvement. By contrast, anger showed an ampler peak amplitude related to the higher involvement experienced by the subjects.

Direct/Incidental Task Comparison (Experiment 1 and 2). A direct comparison between the two types of task (direct and incidental) was conducted by four mixed-design ANOVAs (Type, 4 × Site, 4 × Task, 2; and Type, 4 × Task, 2 × Lateralization, 2), applied to both peak an latency dependent measures. The first ANOVA showed a main effect for type, $F(3, 39) = 15.09$, $p = .001$, $\eta^2 = .51$, and site, $F(3, 39) = 12.33$, $p = .001$, $\eta^2 = .48$, but not for task, $F(1, 39) = 1.43$, $p = 0.26$, $\eta^2 = .17$. For the interaction effects, Task × Site was significant, $F(6, 39) = 7.62$, $p = .01$, $\eta^2 = .34$. Specifically, in addition to the type effect, the successive comparisons showed a more Pz, $F(1, 39) = 8.76$, $p = .001$, $\eta^2 = .\ 04$, and Cz, $F(1, 39) = 17.26$, $p = .001$, $\eta^2 = .53$, site of N200 for direct than incidental task. On the contrary, frontal site was not differentiated, $F(1, 39) = 1.24$, $p = .26$, $\eta^2 = .16$. The latency measure was entered in a successive mixed-design ANOVA. No specific main or interaction effect was significant.

The second set of ANOVAs showed significant differences between type, $F(3, 39) = 8.93$, $p = .001$, $\eta^2 = .\ 37$; task, $F(1, 39) = 13.54$, $p = .001$, $\eta^2 = .\ 60$; and the Type × Lateraliza-Lateralization interaction effect, $F(3, 39) = 10.16$, $p = .001$, $\eta^2 = .49$. As showed by successive comparisons, a more right distribution of N200 was found for anger and sadness than happiness, respectively, $F(1, 39) = 16.57$, $p = .001$, $\eta^2 = .54$; $F(1, 39) = 8.78$, $p = .001$, $\eta^2 = .49$; and neutral, $F(1, 39) = 16.17$, $p = .001$, $\eta^2 = .55$; $F(1, 39) = 15.18$, $p = .001$, $\eta^2 = .53$, faces in direct task. On the contrary, no differences were found in incidental condition between the emotions for the cortical side distribution. No differences were revealed for peak latencies.

Discussion

The second experiment allowed us to point out some main cortical effects due to the different types of task. First, we can state the existence of a specific cortical effect devoted to emotional feature analysis, that is a specific marker for emotional configuration, not only related to the comprehension of a facial stimulus but responsive for emotional features of the face. Second, we can state that this cortical effect is activated independently from type of task, as it was observed in the same form for both the direct and the indirect elaboration. In fact, from a morphological point of view, we revealed that direct task produces an analogous peak variation of the incidental task, represented by the N200 ERP effect. We can explain this result stating that the emotional encoding is an automatic process, devoted to extrapolate the emotional meaning from face regardless of the type of task (Balconi & Pozzoli, 2003b; Vuilleumier, Armony, Driver, & Dolan, 2001). This supposition is compatible with a model in which simple perception of emotional faces entailed activation of specific recognition processes, indexed by the N200 ERP effect (Winston et al., 2003). Nevertheless, consequent to a direct comparison between the two types of task, some consistent differences were found for N200 as a function of direct and incidental elaboration of the stimulus in terms of the cortical distribution of the negative deflection. Whereas in the incidental task N200 was mainly distributed on the parietal site, in the direct elaboration of emotional faces a central localization was observed in addition to the parietal one. These differences are in line with what was found in previous studies that stated a middle larger effect for a direct semantic task (Otten & Rugg, 2001). Nevertheless, we could explain this topographical difference by supposing that emotional encoding in the two tasks may have engaged neurophysiologically equivalent activity in differently located neural generators. Alternatively, encoding in the two tasks may have engaged neurophysiologically distinct activity in a different set of generator populations. Although the present data do not allow a choice between these two possibilities, they do allow the conclusion that ERP subsequent encoding in a direct task is not simply a stronger version of ERP subsequent encoding an incidental task, as our findings suggest that emotional encoding is supported by multiple neural systems. Successive research should test the significance of the cortical difference in N200 distribution as a function of direct/incidental encoding.

A striking finding of this research was the type of emotion effect. The same differences in N200 modulation observed as a function of high-arousing facial emotion (anger) compared with less arousing (happiness and sadness) and more negative (anger) compared with positive (happiness) emotions was registered in both types of the task. Therefore, if N200 functions as a cognitive marker of the specific emotional content of faces, it appears similarly sensitive to the motivational value of emotional stimuli. The fact that the motivational features of faces can affect both the implicit and explicit comprehension of emotions allow us to suppose that the degree of arousal may act in emotion comprehension and that this factor has a main role in determining the cognitive response of the stimulus by the subject. Moreover, the study indicates that a subject can discriminate between types of facial emotions even when facial emotion perception is not task relevant, concomitant with the idea that facial expression is processed automatically (Dolan et al., 1996; Vuilleumier et al., 2001).

Finally, an interesting effect was the lateralization observed as a function of type of emotional faces in the direct task. In fact, negative expressions (anger and sadness) showed a more right distribution of N200 than positive emotion (happiness). It should be considered a main topic to be explored in the future, as it is an interesting trend that identifies the contribution of left–right lateralization effect as a function of emotional content of the face (Davidson, 1993). In this perspective, future research has to consider more exhaustively the lateralization effect. Thus, due to the reduced power of ERP measures for the localization effect, the cortical distribution of the peak variations and its significance for the cognitive processes underlying is an issue to be explored in the future.

GENERAL DISCUSSION

In the present research we explored the processes of encoding of emotional facial stimuli in two different conditions of elaboration, direct and incidental tasks, by ERP variations. Here we summarize the main results of the two experiments and their potential value for both the experimental and clinical level.

Encoding Process

The elaboration of emotional facial expressions appears indexed by a specific ERP effect, the negative deflection N200. The emotional specificity of N200 is underlined by the main differences observed between emotional and neutral stimuli. In line with the Bruce and Young (1998) model, we can postulate that the encoding of facial expression is a separate cognitive process, as shown by the fact that emotional faces had a significantly higher N200 effect than neutral faces. In addition, it can be considered sensitive to the specific emotional content of faces, as it was observed to be varied in amplitude as a function of type of emotion. Second, it was related to the motivational significance of the stimulus for the subject. On one hand, the modulation of peak amplitude is affected by the emotional pattern: Anger expression showed an increase in peak amplitude compared to happiness and sadness. On the other, we found a significant correlation between peak increasing as subjects appear more emotionally aroused and attentively involved by the stimulus (high arousal, negative faces). The correlational measures furnished a clear evidence of the direct relationship between subjects' evaluation in terms of arousal and peak amplitude variations. Recent research emphasizes that the motivational relevance of some emotional stimuli is a primary determinant of selective attention: Somatic, autonomic, and cortical events associated with orienting are automatically activated by more emotionally arousing representations in a variety of paradigms, independent from instructional direction and from task condition, because the relevance of interest of the stimulus is pretask or ''intrinsic'' (P. J. Lang et al., 1997). From this perspective, the significance of emotional expression for the subject, in terms of their low/high threatening power, can influence both the physiological (i.e., arousal) and the cognitive level (mental processes and attentional effort), with important reflexes on ERP correlates (Balconi et al., 2009; Balconi & Pozzoli, 2003b; Frijda, 1986; Keil et al., 2002; P. J. Lang et al., 1993; Schorr, 2001; Wild et al., 2001). Negative arousing emotions (like fear or anger) are expressions of a situation perceived as threatening for our own safeguard, and, for this reason, they require an increasing level of attention (Balconi & Pozzoli, 2008; Ellsworth & Scherer, 2003). On the contrary, positive emotions like happiness express the low-threatening value of the situation, and for this reason they do not require an increasing of arousal and attentional effort.

Furthermore, the absence of differences in the cortical distribution of the peak related to type of emotion is a fact to be considered here. In fact, whereas the idea of the right hemisphere advantage in facial identity recognition has been extended to facial expression processing, our results did not show a clear superiority of one hemisphere in the encoding of the emotional face. However, it should be pointed out that recent data exist indicating that the right dominance in facial expression recognition is modulated by variables such as the task requirements, which can mediate the right advantage. Therefore, the lateralization of ERPs is a main aspect to be considered in relationship with task manipulation, as we discuss successively.

Effect of Type of Task on Encoding

We can summarize the task effect for encoding processing of the emotional face into two main points: the cortical distribution of the N200 on the scalp and the lateralization of the peak deflection. A main result of task manipulation was a ''cortical distribution effect,'' as we observed a more parietal and central localization of N200 for direct compared to incidental condition, the latter being only posterior distributed. It follows from the foregoing conclusion that at least one aspect of the cognitive operations associated with emotional encoding in the two tasks could differ, because a more extended cortical area appears to be implicated in the direct encoding of emotional faces. For this reason we can conclude that either the cognitive processes that enable encoding, the type of information the processes act upon, or both, differ depending on the nature of the task.

A second result related to task manipulation is the right lateralization effect observed for negative emotions in comparison with positive and neutral emotions for the direct task but not for the incidental task. In fact, a specific right lateralization for negative emotions was found when the subjects had to be attentive to the emotional content of faces. A considerable amount of research has investigated the lateralization of emotional processing. According to "right hemisphere hypothesis," the right hemisphere plays a superior role in emotional processing, such as recognition of both positive and negative emotions (Borod et al., 1998). An alternative view (the "valence hypothesis") is that the right hemisphere primarily mediates negative rather than positive emotions (Davidson, 1993). In a recent review, Davidson, Jackson, and Kalin (2000) suggested that right anterior brain regions are specialized for the production and generation of certain negative rather than positive emotions, whereas right posterior regions are involved in the perception of emotions, irrespective of their valence. Our data seem to be better explained by the valence model of lateralization, because the "right hemisphere superiority" is not at all able to justify the distinction between positive/negative cortical localization revealed here. But why did we find this effect exclusively in a direct condition? It is hypothesizable that this localization effect is a consequence of differences in attentional effort for processing the stimuli, such as tasks that make more prominent emotional content of face could induce a specific cortical activation, with a specific facilitation mechanism for negative emotion processing in the right side of the scalp.

The present findings allow an analysis of the significant effect of implicit and explicit processing of emotional information. Some interesting differences in terms of cortical localization of the two processes were elucidated. Thus we may propose that, although people use similar neural pathways to respond to emotional faces quite apart from the degree of task explicitness, significant distinctions should be done between a more anterior versus posterior network contribution as a function of type of task. These considerations may have also remarkable effects on a clinical level, as impairments of face processing may be consequent to different types of induced task (with a double dissociation between impairments for direct and indirect encoding of information) with different contributions by distinct cortical correlates.

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