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Consciousness and emotion. ERP modulation and attentive vs. pre-attentive elaboration of emotional facial expressions by backward masking

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Abstract

Attentive and pre-attentive facial stimulus processing is an important topic to explain how people comprehend affective disposition in others. The effect of perceived but not consciously elaborated emotional facial expression was explored in the present research. Secondly, we considered whether ERP can index unconscious mental process of emotion elaboration by using backward masking procedure. Pictures presenting a happy, sad, angry, fearful, disgusted, surprised expressions were submitted to twenty one subjects in both attentive and pre-attentive conditions. The two processes seem to be similar in their nature, since they are marked by analogous peak deflections. Two ERP effects were found, a positive (P300) deflection, maximally distributed on the parietal regions, and a negative (N200) deflection, more localized on the frontal sites. Nevertheless, some differences were found in terms of quantitative modulations of the two peaks. The N200 effect, ampler in attentive condition, may be considered such as an index of conscious processing of emotional faces, whereas the P3 (P3a) effect, higher in pre-attentive condition, was considered a specific marker of the automatic, unconscious process during the emotional face comprehension. The semantic significance of unconscious elaboration and the emotional type effect, as a function of arousal and valence, were discussed.

Key-words: attention; consciousness; emotion; ERP measures; facial expression

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1. Introduction

Rapid detection of emotional information is highly adaptive, since it provides critical element on environment and on the attitude of the other people (Darwin, 1872; Eimer & Holmes, 2007). Indeed faces are a critically important source of social information and it appears we are biologically prepared to perceive and respond to faces in an unique manner (Ekman, 1993). Recent investigations of emotional processing have uncovered components of a complex network for the detection and analysis of emotionally significant information from faces. Brain areas generally involved in evaluation of the emotional and motivational significance of facial expressions appear to be mediated by the amygdala and orbitofrontal cortex, while structures such as the anterior cingulate, prefrontal cortex and somatosensory areas are linked to the conscious representation of emotional facial expression for the strategic control of thought and action (Adolphs, 2003).

Nevertheless, there is an increasing evidence supporting the idea that significant affective processes happen outside consciousness (Calvo & Esteves, 2005; Dimberg et al., 2000; LeDoux, 1996). It has been shown that the affective information contained in facial expression is perceived involuntarily (Eastwood & Smilek, 2005), and is able to constrict the focus of attention. Considering the critical social relevance of facial expressions of emotion, it is not surprising that the emotions displayed in facial expression can be perceived even when subjects have no conscious experience of perceiving these expressions. Thus, attentive and pre-attentive facial stimulus processing is an important topic to explain how people comprehend affective disposition in others.

Research on consciousness introduced a distinction between automatic and conscious (Posner, 1978) or automatic and controlled (Shiffrin & Schneider, 1977) information processing. This concept was developed to account for the fact that the selectivity of attention is better described in terms of a flexible and strategic distribution of limited processing resources across stimuli and tasks. The effect of perceived but not consciously elaborated emotional stimulus is critique for a great amount of neuropsychological research, on both normal and pathological subjects (Bunce et al., 1999; Dimberg & Öhman, 1996; Wong et al., 1994). Specifically, facial expressions of emotion are considered unique in their ability to orient the subjective cognitive resources, even if people are unable to process information consciously. Secondly, it was hypothesized that subjects are able to assign a semantic value to the emotional content of faces even in an unaware condition (Dimberg et al., 2000; Wong & Root, 2003). Unconsciously processing for facial stimuli can also be demonstrated in clinical context, such as in case of prosopagnosia. In most cases prosopagnosics appear to recognize familiar faces even though they fail to identify the persons verbally. Therefore, the patients showed an unconscious recognition that cannot be accessed consciously (Tranel & Damasio, 1985).

However, although the existence of unconscious elaboration was accepted, the question concerning its importance for emotional decoding is still open. Only little studies have explored the significance of conscious vs. unconscious face comprehension based on priming effect or subliminal stimulation (Balconi & Lucchiari, 2007; Batty & Taylor, 2003; Holmes et al., 2003). Moreover, an another useful measure to analyze conscious and unconscious perception of faces is the masking procedure. By low intensity and brief exposure, a target stimulus can be made unrecognized when another stimulus is presented simultaneously, shortly before (forward masking), or shortly after (backward masking) (Rolls, 2006). Nevertheless, the effect of this masking technique was not largely used for the emotional face detection. So, we have no precise knowledge of the actual effect of masked emotional stimulus on the elaboration of the target one.

A second main point is that most of the recent research on the detection and analysis of emotionally significant information from face have used fMRI measures, which are based on relatively slow hemodynamic brain responses, and the studies on the time course of emotional processing have been relatively scarce (Simons et al., 2007). Thus these methods need to be completed with measures that provide insights into temporal parameters of emotional comprehension, such as event-related potential (ERP). Specifically, ERP measures are very useful tools to examine the time course of the conscious vs unconscious stimulus elaboration at a very high temporal resolution (Shevrin, 2001; Snodgrass, 2000).

Secondly, by comparing wave profiles between conditions, they furnish a valid measure of the qualitative nature of the emotional mechanisms, checking the resemblance of the underlying processes for attentive and not attentive emotional elaboration (Balconi & Lucchiari, 2007; Brázdil et al., 2001).

For this reason it is interesting to compare ERP profiles in conscious vs. unconscious condition, in order to verify the similarity of the comprehension processes. The first main topic of the present research was to explore whether ERP can index unconscious mental process in case of emotion elaboration by using backward masking procedure. Secondly, a main issue to be considered is related to the semantic significance of unconsciously processed stimulus (Stenberg et al., 2000). Specifically we intend to analyze:

- the resemblance of the two processes, attentive and pre-attentive, from a qualitative point of view (morphological analysis);

- the existence of some differences in terms of the type and the amount of cognitive resources required to process the two types of stimuli (ERP modulation in terms of peak amplitude);
- the temporal course of this processes, with a delayed or anticipated effect for unconscious elaboration (ERP modulation in terms of peak latency).

Previous research have found a general qualitative similarity between conscious/unconscious conditions (Shevrin, 2001). Nevertheless actually it is not clear at what extent the two processes can be analogous, specifically with respect of the semantic value of unconscious face detection.

A specific ERP measure for emotional face comprehension was found, that is an early negative deflection at about 240 ms post-stimulus, related to emotional faces more than neutral faces for an explicit (Streit et al., 2000) or an implicit task (Sato et al., 2001). It was discussed as a cognitive marker of the complexity and the relevance of the stimulus (Carretié & Iglesias, 1995; Eimer & Holmes, 2007). On the other hand, it was interpreted such as an emotional-face index (Balconi & Pozzoli, 2003; Herrmann et al., 2002), able to evidence the conscious comprehension of emotional significance of faces. Based on this evidence, we expected a modulation of N200 as a function of attentive (conscious) vs pre-attentive (unconscious) elaboration. The former condition could be marked by an ampler deflection that signals the attentional resources allocation by the subjects.

The effect of unconscious elaboration for emotional relevant stimuli was tested even through a second ERP effect, the P300 modulation. In general, it was found not to be exclusive for faces, since it was observed for other objects with an emotional content (Bernat et al., 2001). P300 was shown to be related even to unconsciously processed stimuli, that result to be relevant for the subject (Kotchoubey, 2005; Lang et al., 1997). This deflection, generally more posteriorly localized (parietal sites), was found to be related to decisional process, and it is activated even in absence of attentive resource allocation (Polich, 2007). Specifically, a subcomponent of P300, P3a (in contrast to the P3b), is relatively attention-independent and may serve as a component of the response. Moreover, the P3a was previously associated with the automatic aspects of the orienting response that are involved in detecting a relevant (in some cases threatening) stimulus (Liddell et al., 2004). For previous reasons we expected that responses to emotional face should be marked by P3a component in a greater measures for pre-attentive processing than for attentive one. This should put in evidence the rapid detection of emotional relevant stimuli, that will be processed in more details in a successive cognitive conscious phase.

The comparison between attentive and pre-attentive processes was conducted even by considering the temporal effect they produced. As shown by some studies, delayed unaware information processing represents a distinctive feature of unconscious visual perception (Balconi, 2006; Bernat et al., 2001; Junghöfer et al., 2001), and it was explained as a consequence of a more complex process underlying unconscious elaboration. Contrarily, some other studies have found an anticipated peak modulation for unconscious compared to conscious perception (Brádzil et al., 2001). Thus the time of emergence of peak variation as a function of consciousness is a main topic to be considered, in order to have more information on the nature of the cognitive processes implicated.

An another interesting point not exhaustively considered by previous research was the effect produced by the emotional content of faces (Balconi & Lucchiari, 2007; Eimer, 2000; Herrmann et al., 2002). In comparison with other research our study explored an ampler range of emotions (six emotions: anger, fear, surprise, disgust, joy and sadness). Motivational significance of emotions has an effect on subjects' responses, since it was found that emotionally salient stimuli (unpleasant compared to neutral) generate greater magnitude of ERP response, for both N200 (Balconi & Lucchiari, 2005; Junghöfer et al., 2001) and P300 (Morita et al., 2001; Schupp et al., 2000) measures. Thus we hypothesized that significance of emotional expressions in terms of the importance and of the experiential meaning they have for the subjects could influence the degree of attentional resources allocated, with an effect on ERP amplitude modulation (Frijda, 1996; Schorr, 2001). The impact of different emotional patterns should be tested for both attentive and pre-attentive mechanisms, and the attended effect has been theoretically related to motivated attention, in which motivationally relevant stimuli naturally arouse and direct attentional resources (Hamm et al., 2003; Keil et al., 2002).

As suggested by Russell's circumflex model (Russell, 2003; Russell & Bullock, 1985), each emotion and its facial expression represents a specific response to a particular kind of significant event, that is it is evaluated by the subject in line with its motivational significance. This appraisal process is regulated by two main criteria: the arousing power of the stimulus (high or low); the valence of the emotional stimulus (positive or negative). Thus, the entire emotional universe is representable by the two axes, and the "significance" attributed to the emotional expressions may have a direct effect on the cognitive level and the degree of attention allocated. Based on these considerations, a direct comparison between the emotions is required. Emotional type-related ERP waves were compared, in order to judge in more details the effect of arousal/valence on ERP modulation, for both attentive and pre-attentive condition.

Finally, localization effect of peak deflections is a critique point to be discussed. Variations of peak distribution on the scalp surface as a function of stimulation condition (conscious vs unconscious) (Gazzaniga, 1993) and emotional content (type of emotion) was monitored (Smith & Bulman-Fleming, 2004). The intervention of different cortical modules for conscious and unconscious information elaboration (lateralization effect) or with respect of specific facial pattern (emotion-effect) is an important point that requires to be elucidated. On this level, divergent results were obtained, even if previous research used a reduced range of emotions, fact that prevents them to answer exhaustively to this matter.

2. Method

2.1. Stimulus material and subjects

Stimulus materials were taken from the set of pictures of Ekman and Friesen (1976). They were black and white pictures of an actor, presenting respectively a happy, sad, angry, fearful, disgusted, surprised and neutral face.

Twenty one healthy subjects took part in the experiment (nine women, age range 23-30, mean = 23.62, SD = 1.53), after given informed consent. They were students of Psychology at the Catholic University of Milan, with normal or corrected-to-normal visual acuity.

2.2. Backward masking procedure

During the experiment we used a backward masking procedure. Each facial stimulus (target) was presented for either 30 (low exposure) or 200 (high exposure) ms, followed by an another face presented for 200 ms (masking stimulus). Interstimulus interval was 30 or 200 ms respectively for pre-attentive vs. attentive condition (Bernat et al., 2001; Brázdil et al., 1998; Liddell et al., 2004). The short stimulus presentation in pre-attentive condition prevents the subjects to have a clear cognition of the stimulus. In the current study we employed an objective threshold for pre-attentive condition. It was defined by an identification procedure, the case where stimulus is perceived by the subject no more than in 50% of the times (Liddell et al., 2004; Merikle et al., 2001). The post-hoc briefing confirmed that subjects were unable to detect target stimulus in the pre-attentive condition.

In total there were 140 target-mask pairs in each threshold condition (each expression type was presented twenty times for condition).

2.3. Procedure

Subjects were seated comfortably in a moderately lighted room with the monitor screen positioned approximately 100 cm in front of their eyes. Pictures were presented in a randomised order in the center of a computer monitor, with a horizontal angle of 4° and a vertical angle of 6° (STIM 4.2 software). During the examination, participants were requested to minimize blinking. They were required to observe the stimulus during ERP recording (passive task). In the pre-attentive condition it was emphasized that sometimes the target face would be difficult to see, but the subjects were requested to concentrate as best they could on stimulus, since they would be asked question about these stimuli after the ERP recording. An explicit response to the emotional features of the stimulus was not required. This was done for three main reasons: to assure a real passive task (implicit elaboration of emotions); to not cause them to be more attentive to the emotional stimuli than the neutral ones; to not introduce an unequal condition between conscious and unconscious stimulation. Third, the absence of an explicit response avoids confounding motor potentials in addition to brain potentials. Prior to recording ERPs, subjects were 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 (14 trials, each expression type repeated twice).

2.4. EEG recording

The EEG was recorded with a 32-channel DC amplifier (SYNAMPS system) and acquisition software (NEUROSCAN 4.2). An ElectroCap with Ag/AgCl electrodes was used to record EEG from active scalp sites referred to earlobe (10/20 system of electrode placement). Additionally two EOG electrodes were sited on the outer side of the eyes. The data were recorded using sampling rate of 501 Hz, with a frequency band of 0.1 to 60 Hz. The impedance of recording electrodes was monitored for each subject prior to data collection and it was always below 5 kΩ. After EOG correction and visual inspection only artefact-free trials were considered. Only fourteen electrodes were used for the successive statistical analysis (four central, Fz, Cz, Pz, Oz; ten lateral, F3, F4, C3, C4, T3, T4, P3, P4, O1, O2).

3. Results

3.1. Behavioral data

The subjects were asked to analyze the stimuli viewed after the experimental section. They evaluated the emotional significance of each expression by a categorization task. The seven emotional categories were correctly recognized. Specifically a correct identification and a high judgement agreement was done for happy (90.5%; on a five-point Likert scale: M = 4.37; SD = .60), sad (76.2%; M = 4.25; SD = .86), angry (71.4%; M = 4.13; SD = .74), fearful (90.5%; M = 4.53; SD = .77), disgusted (90.5%, M = 3.89; SD = .94), surprised (90.5%, M = 4.37; SD = .68) and neutral (90.5%; M = 3.84; SD = 1.01) faces.

3.2. N200: amplitude and latency

The dependent variables of peak amplitude and latency were entered into a three-way ANOVA using the following repeated factors: condition (2: attentive/pre-attentive) x site (4: frontal/central/parietal/ temporal) x emotion (7). To assess localization, frontal (F2 and F3), central (C4, Cz and C3), parietal (P2, Pz and P3) and temporal (T4 and T3) sites were calculated. Type I errors associated with inhomogeneity of variance were controlled by decreasing the degrees of freedom using the Greenhouse-Geiser epsilon.

Regarding peak amplitude, the repeated measure ANOVA showed a significant main effect for condition ($F(1,20) = 29.36$, $P = .001$, $\eta^2 = .59$), with an increased amplitude in attentive condition, and for site ($F(3,20) = 26.44$, $P = .001$, $\eta^2 = .57$), but not for emotion ($F(6,20) = 1.06$, $P = .38$, $\eta^2 = .05$) (Figure 1).

Interaction effect condition x site was also significant ($F(3,20) = 16.90$, $P = .001$, $\eta^2 = .46$). Planned contrasts applied to main effect of site showed that frontal sites were more activated than central ($F(1,20) = 29.21$, $P = .001$, $\eta^2 = .59$), parietal ($F(1,20) = 33.33$, $P = .001$, $\eta^2 = .62$) and temporal ($F(1,20) = 49.41$, $P = .001$, $\eta^2 = .71$) ones (Figure 2).

Moreover, simple effects applied to condition x site interaction showed an increased frontal and central activity in comparison with parietal and temporal ones.

For the latency measurement, the ANOVA showed a significant main effect for condition ($F(1,20) = 18.95$, $P = .001$, $\eta^2 = .49$), with a shorter latency in pre-attentive condition, site ($F(3,20) = 40.28$, $P = .001$, $\eta^2 = .67$) and emotion ($F(6,20) = 2.56$, $P = .04$, $\eta^2 = .11$).

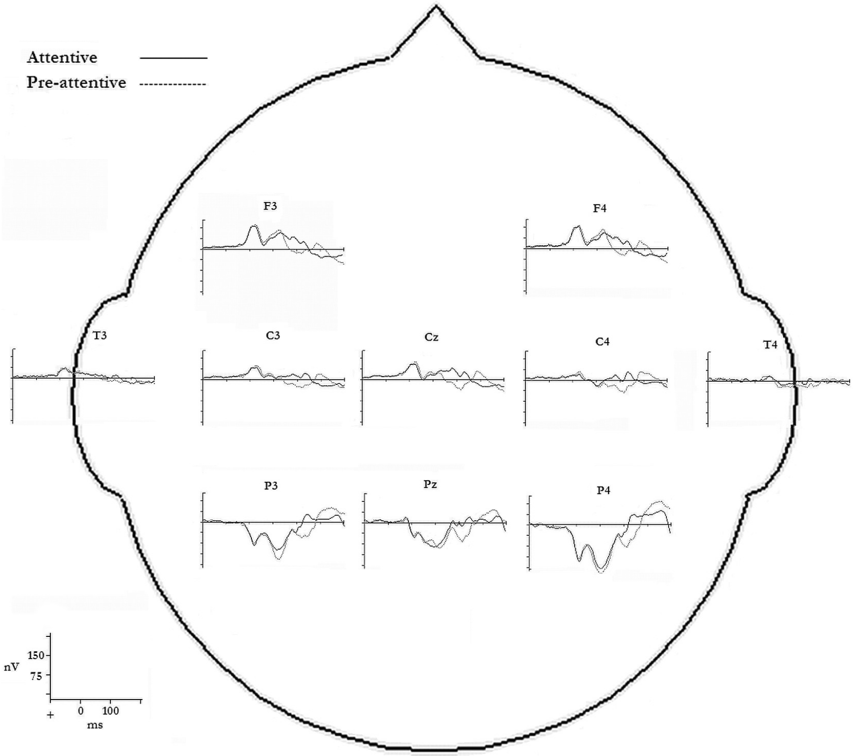

Figure 1. Waveforms of grand-averaged ERPs for attentive and pre-attentive condition

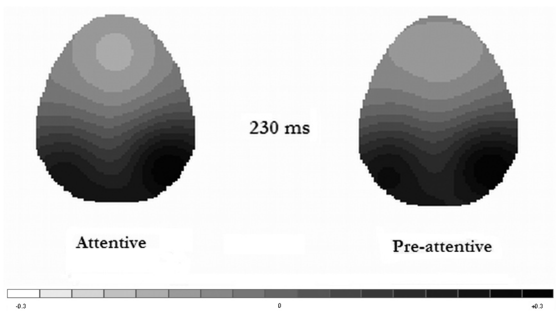

Figure 2. Topographical mapping of N200 for attentive and pre-attentive condition

Interaction effect condition x site was also significant ($F(3,20) = 3.39$, $P = .03$, $\eta^2 = .14$). As shown by contrast analysis applied to main effect of site, peak latency was shorter for frontal sites respectively compared with central ($F(1,20) = 11.01$, $P = .003$, $\eta^2 = .36$) and parietal ($F(1,20) = 56.86$, $P = .001$, $\eta^2 = .74$) ones. Contrasts applied to main effect of emotion showed a reduced latency for surprise in comparison with anger ($F(1,20) = 5.96$, $P = .02$, $\eta^2 = .23$) and for happiness in comparison with sadness ($F(1,20) = 6.72$, $P = .01$, $\eta^2 = .25$). Moreover, neutral stimulus differed from anger ($F(1,20) = 6.37$, $P = .02$, $\eta^2 = .24$) and sadness ($F(1,20) = 12.70$, $P = .002$, $\eta^2 = .39$), with a decreased latency.

3.3. P300: amplitude and latency

The same statistical analyses conducted for N200 effect were applied to P300. For the peak amplitude measurement, a significant main effect was found for condition ($F(1,20) = 66.41$, $P = .001$, $\eta^2 = .77$), with an increased amplitude in pre-attentive condition, site ($F(3,20) = 37.56$, $P = .001$, $\eta^2 = .65$) and emotion ($F(6,20) = 3.52$, $P = .007$, $\eta^2 = .15$) (see Figure 1). Interaction effect condition x site was also significant ($F(3,20) = 5.91$, $P = .001$, $\eta^2 = .23$). Contrasts applied to main effect of site showed that parietal sites were more activated than frontal ($F(1,20) = 47.16$, $P = .001$, $\eta^2 = .70$), central ($F(1,20) = 16.43$, $P = .001$, $\eta^2 = .45$) and temporal ($F(1,20) = 42.53$, $P = .001$, $\eta^2 = .68$) ones (Figure 3).

Contrast analysis applied to main effect of emotion showed differences between happiness and sadness ($F(1,20) = 10.32$, $P = .004$, $\eta^2 = .34$), and fear and sadness ($F(1,20) = 5.20$, $P = .03$, $\eta^2 = .21$), with an increased amplitude for happiness and fear respectively. Moreover, neutral stimulus differed from surprise ($F(1,20) = 14.53$, $P = .001$, $\eta^2 = .42$) and happiness ($F(1,20) = 7.3$, $P = .01$, $\eta^2 = .27$), with a decreased amplitude in comparison whit both (Figure 4). Simple effects applied to condition x site interaction showed in the pre-attentive condition an increased parietal activity in comparison with frontal, central and temporal sites.

Regarding peak latency, the ANOVA revealed a significant main effect for site ($F(3,20) = 16.64$, $P = .001$, $\eta^2 = .45$), but not for condition ($F(1,20) = .16$, $P = .69$, $\eta^2 = .01$) and emotion ($F(6,20) = .31$, $P = .93$, $\eta^2 = .01$). Some interaction effects were also significant: condition x emotion ($F(6,20) = 2.47$, $P = .02$, $\eta^2 = .11$) and condition x site ($F(3,20) = 48.40$, $P = .004$, $\eta^2 = .19$). Planned contrasts applied to main effect of site showed reduced latency for parietal sites respectively compared with frontal ($F(1,20) = 21.30$, $P = .001$, $\eta^2 =.52$), central ($F(1,20) = 8.93$, $P = .007$, $\eta^2 = .31$) and temporal ($F(1,20) = 12.31$, $P = .002$, $\eta^2 = .38$) ones.

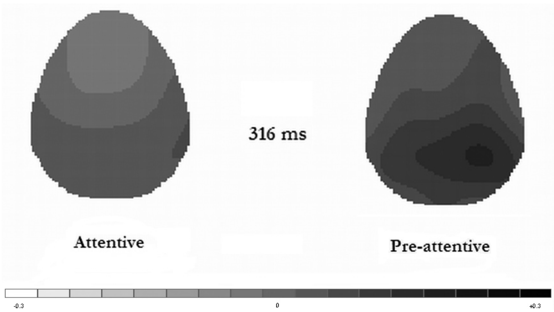

Figure 3. Topographical mapping of P300 for attentive and pre-attentive condition

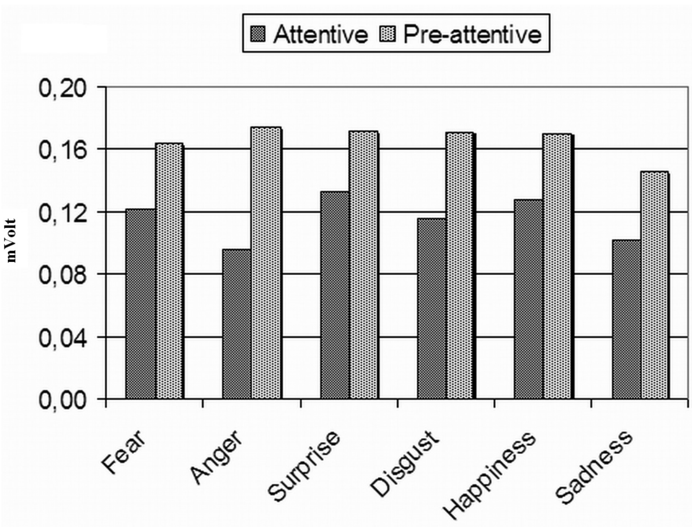

Figure 4. Peak amplitude of P300 for each emotion in attentive and pre-attentive condition

4. Discussion

Numerous studies have sought to demonstrate that emotional information can be perceived without awareness. The conclusion that emotional facial expressions can be perceived without consciousness is not surprising given the importance of emotional information for human survival. Nevertheless, in previous research what remains unclear was the specific semantic value this perception has and in what measure the subject can elaborate the unconscious emotional stimuli. Three main points will be considered below, specifically the comparison between attentive and pre-attentive processing; the time differences of the conscious/unconscious elaboration; the emotion type effect on the stimulus comprehension in both conditions. Finally, a conclusive remark will be made on the broad significance of ERP for unconscious elaboration of emotional face.

4.1. Attentive vs. pre-attentive comparison

A first conclusion is that the ERP results may index unconscious processes related to emotion comprehension. Secondly, the two processes, attentive and pre-attentive, have an ample space of overlapping, since they are marked by analogous peak deflections, respectively the negative N200 and the positive P300 effects. They were morphologically analogous for observable waveforms: the two waves are quite similar with respect of the profile. Specifically, on one hand, N200 was found to be a negative deflection more distributed on the frontal sites for both conscious and unconscious stimulation. On the other hand, the P300 found for attentive and pre-attentive conditions seems to be an analogous of the classical P300 component of ERPs, and it has its peak maximum in the parietal region.

Nevertheless, attentive and pre-attentive modalities ingenerate different peak modulations. Specifically, in terms of quantitative variation of waves, we can consider two distinct planes of analysis: waves appear quite differentiated as a function of their amplitudes (peak intensity) and their temporal effect (peak latency).

About N200, the attentive elaboration was marked by an ampler deflection than the pre-attentive one. Thus, possibility to consciously discriminate the stimulus and to attribute an emotional significance to it could be marked by the increased amplitude of the negative deflection. This deflection was in fact intended such as a marker of the attention allocation and an index of an emotion-specific cortical response (Balconi & Pozzoli, 2003; Herrmann et al., 2002; Streit et al., 2000).

About the cortical localization of N200, it was found to be an anterior (frontal) phenomenon. Nevertheless, it was mainly distributed exclusively on the frontal sites in case of unconscious processing, and on frontal and central in case of conscious processing. The differences in distribution of N200 may induce to conclude in favour of the existence of different cortical networks in response to different conditions.

Even the second deflection, the positive P300, appears to have different peak amplitude as a function of attentive/pre-attentive elaboration. But in this case the reverse direction was collected in terms of amplitude modulation: an ampler positive wave was found for unconscious pre-attentive stimulation, that was more posteriorly marked. Specifically, this cortical distribution suggests a resemblance with the P3a component, that was related to the encoding of information that may be elaborated under the level of consciousness and that needs for a successive elaboration by higher order mechanisms (Kotchoubey et al., 2002; Lang et al., 1997; Polich, 1989). As shown in other studies, P300 was observed even in case of an automatic elaboration of relevant information that has no access to an aware comprehension: for example, greater amplitude value of P300 was found in response to unrecognized emotional stimuli (Brázdil et al., 1998; 2001). Moreover, the sensitivity of this index to different emotions and its modulation as a function of the emotional content is a clear evidence that it allows for a semantic discrimination, even in case of an implicit or an unconscious processing (Kotchoubey, 2005). In other terms, pre-attentive elaboration may have a semantic value, since it was able to derive emotion-related information that characterizes the stimuli.

4.2. Time of processing

The peak latency measure was a second main point to be elucidated. An anticipated N200 peak was found for pre-attentive stimulation. Thus, we obtained a significant reduction of time in the subjects' response for unconscious condition. It is plausible to explain the extra-time required to elaborate consciously the facial stimuli considering the necessity to process in a detailed manner the nature and the emotional content of faces. Nevertheless, this result appears to be in contrast with previous research that found a delayed peak for unconsciously processed stimuli (Bernat et al., 2001; Junghöfer et al., 2001). These contrasting data could be explained taking into account the sensible difference existing between the methodologies used to induce an unconscious perception, i.e. subliminal vs. masking procedure.

On the contrary, in case of P300 the temporal effect was absent as a function of condition: no delayed peak was observed in pre-attentive elaboration. It induces to consider that the automatic comprehension of an emotional stimulus in a pre-attentive form, marked by an ampler P300, is a rapid mechanism. An adjunctive interesting information regards the localization effect for unconscious processing, since an anticipated positive deflection was found within the posterior area, where the P300 was generally found to be ampler. Thus, we can hypothesize that the pre-attentive information is at first elaborated within the posterior sites, and that this preliminary unconscious comprehension attends for a successive (conscious) process, that requires a more anterior activation of the scalp sites.

4.3. Emotion type effect

An interesting effect was found for P300, where different responses by the subjects were observed for some types of emotions. The first main fact is that the direction of the differences was the same in attentive and pre-attentive condition, with a decreased peak amplitude not only for neutral faces but even for the low arousal, negative emotion, that is sadness, if compared with high arousal emotions (like happiness, fear, and surprise). It induces to consider that high arousal faces with both a negative or a positive valence have a significant impact on subject's response and that even the pre-attentive processing is oriented to reveal this prominent emotional information.

Our results allowed us to extend the range of emotions to be compared and to explore in details the functional value of facial expressions. It is assumed that, as a function of the salience, stronger for negative or high arousal stimuli, each facial expression has a specific site along a continuum, fact that was revealed by the increased intensity of the positive deflection P300. From an evolutionary perspective, some emotions appear to be prominent as human safeguard (Lang et al., 1993), since they facilitate the survival of the species. The immediate and appropriate response to these emotionally salient stimuli confers them an adaptive value: between the others, more negative and threatening facial stimuli (such as surprise or anger) may evoke greater arousal than unthreatening stimuli, fact that may produce specific physiological and cognitive reactions, marked by an increased P300 peak. The rapid response to an unconsciously perceived facial expression is likely adaptive because it prepares us to react in an effective manner to the presence of highly significant (socially relevant or threatening) situation.

Moreover, a substantial amount of research has established that unconsciously perceived facial expressions elicit emotional responses that include various form of physiological arousal. In particular, when a more salient facial expression is perceived without awareness, subjects show a pattern of physiological arousal that includes, between the others, larger skin conductance response (Dimberg & Öhman, 1996), and ERP measures (Balconi & Lucchiari, 2007; Liddell et al., 2004).

The circumflex model allows to support this theoretical explanation, since the model has postulated that facial expression of emotion is representable such as a communicative cue that the subject produces in response to a particular kind of significant event (Russell, 2003; Russell & Bullock, 1985). Negative, high arousal emotions (like anger, fear, and surprise) are expressions of a significant situation perceived as threatening (high-arousing) and of the subject's inability to face up the event (negative). On the contrary, positive high-arousal emotions, like happiness, communicate the effectiveness in managing the social relationships, and they have a high positive value in terms of social regulators. Thus, the circumflex model allows to predict that the structure of emotional expression and comprehension is related to a two-dimensional space, the axes of which could be interpreted as pleasure-displeasure and arousal-sleepiness. In particular, the two orthogonal axes support for a clear categorization of emotion perception, subdividing the entire emotional universe as a function of arousal response produced by emotional patterns, in addition to the negative/positive value they have.

5. General conclusion: masking effect, ERPs and emotional faces

An important result is that attentive vs. pre-attentive comparison provides compelling evidence that emotional stimuli are perceived and semantically analyzed even when they are presented under stimulus conditions that make it impossible to have a conscious comprehension of information. It enables us to answer about the semantic significance of the pre-attentive elaboration: the subjects, although unaware, can attribute an emotional value to the facial expressions. This fact is in line with previous research that have used autonomic (skin conductance measures or cardiovascular indexes) measures or conditioned responses (Öhman, 1999), that pointed out unconscious affective stimuli may have effect for the appraisal of conscious stimuli. It seems that the information presented under pre-attentive conditions may be perceived and processed on a higher level even if the subject is not aware of this information (Dehaene et al., 2006).

Specifically, regards P300 modulation, in the present research it was shown the effect due to the pre-attentive processing that masking procedure may induce. Masking prevents from consciously processing faces and their emotional content, even if maintains a clear responses by the subjects in terms of an automatic process that allow them to extrapolate the semantic significance of facial stimuli. At this regard, we can underline some interesting improving from previous studies that used only subliminal stimulation method by reduced exposure. Indeed, some contrasting results were obtained in some research on ERPs about the "semantic effect" in unconscious perception, since they did not found modulation of unconscious response by the emotional content. Nevertheless, it has to be noted that these studies have used subliminal stimulation with very low subliminal threshold (in general 10 ms or lower threshold). Thus, we can explain these result divergences as due to the fact the two methodologies (backward masking and subliminal stimulation) are finalized to explore quite different unconscious processes, pre-attentive for masking condition and totally unaware in subliminal condition (Dehaene & Changeux, 2004; Dehaene et al., 2006).

For future research a more specific analysis of semantic process under attentive/pre-attentive conditions should be included. For example, it should be focalized how a specific "semantic-marker" such as N400 effect would be modulated by the semantic content of faces. Previous studies revealed, in fact, that conscious vs. unconscious semantic activation may modulate even the later N400 (Kiefer & Spitzer, 2000). Moreover, the direct effect of varying time of exposure of emotional stimuli for both subliminal and masking procedure could improve our knowledge on pre-attentive and unaware processing.

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