

Implicit and explicit categorization of natural scenes

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Abstract: Event-related potential (ERP) studies have consistently found that emotionally arousing (pleasant and unpleasant) pictures elicit a larger late positive potential (LPP) than neutral pictures in a window from 400 to 800 ms after picture onset. In addition, an early ERP component has been reported to vary with emotional arousal in a window from about 150 to 300 ms with affective, compared to neutral stimuli, prompting significantly less positivity over occipito-temporal sites. Similar early and late ERP components have been found in explicit categorization tasks, suggesting that selective attention to target features results in similar cortical changes. Several studies have shown that the affective modulation of the LPP persisted even when the same pictures are repeated several times, when they are presented as distractors, or when participants are engaged in a competing task. These results indicate that categorization of affective stimuli is an obligatory process. On the other hand, perceptual factors (e.g., stimulus size) seem to affect the early ERP component but not the affective modulation of the LPP. Although early and late ERP components vary with stimulus relevance, given that they are differentially affected by stimulus and task manipulations, they appear to index different facets of picture processing.

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The ability to organize the world into meaningful and appropriate groupings is necessary for determining an organism's behaviour in terms of capacity to achieve adaptive responses in different situations. A number of studies using simple stimuli and explicit tasks suggest marked limits to the capacity of visual attention. In contrast, we all know that despite the perceptual complexity of natural scenes, the processing of everyday scenes is almost instantaneous and feels effortless. Several recent studies have confirmed this notion and have experimentally demonstrated the impressive speed with which natural scenes are categorized. Moreover, it has been demonstrated that when natural scenes are motivationally relevant they rapidly capture attentional resources leading to automatic categorization. This paper provides an overview of

recent studies on natural scene categorization and motivated attention.

Categorization of natural scenes

Since the 1970s, Mary Potter and colleagues have crafted a careful series of rapid serial visual presentation (RSVP) studies showing that natural objects belonging to a target category may be classified remarkably quickly (Potter, 1975, 1976). In these studies, a rapid sequence of unrelated pictures is presented and an immediate semantic detection is required; for example, participants had to respond when they saw a picture of “a dog” (which they had never seen before), presented within a sequence of 16 pictures. The results of these studies suggested that picture scenes are understood and become immune to visual masking within about 100 ms.

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Evidence from human event-related potentials (ERPs) also gives cause to expect that “early” processing occurs considerably quicker than is commonly thought. [Thorpe et al. \(1996\)](#) investigated how long the visual system takes to perceive and understand a complex natural image through a paradigm in which subjects were asked to decide whether or not a briefly displayed colour picture contains an animal. This study revealed an early ERP difference between target (image with animal) and distractor (image without animal) trials that started roughly 150 ms after stimulus onset. Similar findings have been reported when participants had to categorize complex scenes on the basis of the presence or absence of a clearly artificial category: means of transport ([VanRullen and Thorpe, 2001](#)).

Together with other recent findings ([Li et al., 2002](#); [Kirchner and Thorpe, 2005](#)) the early differential activity starting at 150 ms from stimulus onset has been interpreted as evidence of a specific mode of visual processing, termed “ultrarapid visual categorization” that relies on a parallel and automatic feedforward mechanism ([Fabre-Thorpe et al., 2001](#)).

These findings challenge the conventional view that focused attention is required for high-level visual processing ([Evans and Treisman, 2005](#)). Indeed, several studies have shown that many visual tasks necessitate focused attention, including feature-binding to form objects and change detection in complex scenes ([Treisman and Gelade, 1980](#); [Wolfe and Bennett, 1997](#); [O’Regan et al., 1999](#)).

[Evans and Treisman \(2005\)](#) have recently shown evidence that when participants correctly detected that an animal target was present in a rapid serial visual sequence, they frequently failed to identify the specific exemplar suggesting that detection was based on partial processing. Also, the authors showed that detection of the target was considerably worse in sequences that also contained humans as distractors, presumably because of shared features between animal and human scenes. Based on these findings, [Evans and Treisman](#) suggested that natural scene categorization is characterized by two different stages of processing. A first stage involves a rapid and parallel detection of disjunctive sets of unbound features of intermediate

complexity that characterize a target category. These features of intermediate complexity might be used to discriminate between scenes that do or do not contain the target without necessarily fully identifying it. If the target stimulus is still present after this detection stage, focused attention binds these features to form a more specific representation of the target stimulus.

Initially, the early differential ERP activity was considered to reflect anterior neural generator sites implicated in the inhibition of inappropriate behavioural responses during NoGo trials ([Thorpe et al., 1996](#)). Subsequent research has demonstrated that the early (150 ms) larger negativity elicited by targets compared to distractor stimuli is extensively due to the involvement of occipito-temporal regions in semantic processing of visual stimuli ([Delorme et al., 2004](#); [Rousselet et al., 2004](#)).

Similarly, in the same time window, [Rudell](#) described a posterior evoked potential named recognition potential (RP) to refer to an electrical brain response which occurs when a subject views a recognizable image of words ([Rudell, 1991](#); [Rudell and Hua, 1997](#)) and pictures ([Rudell, 1992](#)). More recently, [Hinojosa et al. \(2000\)](#) showed that the neural generator of the RP is placed mainly in the infero-temporal cortex and they interpreted this potential as related to the processing of semantic-conceptual aspects. The role of infero-temporal neurons in object recognition has been known since the seminal work of [Gross and co-workers \(1973\)](#); furthermore, an important role has been recently ascribed to the prefrontal cortex which receives highly processed visual information from the infero-temporal cortex and orchestrates voluntary, goal-directed behaviours ([Riesenhuber and Poggio, 2002](#); [Freedman et al., 2003](#); [Miller et al., 2003](#)).

The role of the occipito-temporal cortices in natural scene categorization has been examined by [Fize and co-workers \(2000\)](#) in an event-related fMRI study. Results seem to indicate a differential activity in occipito-temporal cortical structures elicited by natural target and distractor scenes ([Fize et al., 2000](#)). Unfortunately, because of the low temporal resolution, fMRI cannot disentangle differences in BOLD activation due to early and late processing of target. However, selective

attention to a specific target stimulus is also reflected at the post-perceptual level of stimulus analysis. Specifically, the P3 component is a hallmark of selective attention. It is a positive-polarity ERP component, typically observed in a time window between 300 and 700 ms post-stimulus and reflects the amount of attention devoted to task-relevant stimuli (Johnson, 1987; Kok, 2001). Following Kok (2001), the P3 is considered to reflect components of attention and working memory with the “event categorization process” as a core element. Most of the previous ERP studies on the categorization of natural scenes used a go/no-go task making the late differential activity difficult to interpret because the target and non-target conditions were unbalanced in terms of motor activation (Rousselet et al., 2004; Macé et al., 2005).

In a recent study, we investigated cortical indicators of selective attention underlying categorization based on target features in natural scenes (Codispoti et al., 2006b). In particular, we were interested in whether the early differential ERP activity exclusively reflects primarily neural generators in the visual cortex responsible for the biased processing of target stimuli or, additional sources related to the generation of a biasing signal in prefrontal areas. Furthermore, with regard to the late differential ERP activity, we tested whether this component reflects target categorization and continued perceptual processing (Ritter and Ruchkin, 1992; Kok, 2001), which would suggest the presence of neural generators in higher order visual processing areas.

As in previous studies by Thorpe and associates (1996), participants had to categorize images according to whether or not they contained an animal. However, our study did not require a go/no-go response and instead subjects responded as to whether an animal was present in the image or not (De Cesarei et al., 2006) using a two-alternative forced-choice task. Pictures were drawn from a large database containing 1200 exemplars with the target and non-target pictures occurring with equal probability; each picture was shown for 24 ms and an inter-stimulus interval of 3–4 s.

Replicating previous findings, the early differential ERP activity appeared as a positive deflection over fronto-central sensor sites and as a

negative deflection over temporo-occipital regions (see Fig. 1). Furthermore, source estimation techniques (Current-Source-Density (CSD) and L2-Minimum-Norm-Estimate) suggested primary sources of the early differential ERP activity in posterior, visual-associative, brain regions, and also a contribution of anterior sources to the early differential ERP. Also, in a time interval 300–600 ms after stimulus onset, target scenes were associated with augmented late positive potentials (LPPs) over centro-parietal sensor sites (see Fig. 1).

Together, these findings seem to indicate that top-down influences early in processing (150 ms) may shape the activity in the ventral visual pathway during selective attention, facilitating categorization based upon target features in natural scenes, and that later (300 ms), task relevant stimuli determine larger allocation of both perceptual and central resources compared with non-target stimuli. Future studies should further clarify the functional and neural meaning of these early and late ERPs components.

Perception and categorization of emotional scenes

Typically, studies on categorization, object recognition and selective attention employ explicit tasks where participants are asked to classify stimuli according to verbal instructions. A special type of categorization is represented by the processing of emotional stimuli. In fact, to the extent that natural images represent motivationally relevant cues, they are able to catch attentional resources and to be therefore quickly categorized (Lang et al., 1997).

Emotional processing has been widely investigated by presenting affective pictures that are effective cues in evoking a broad range of emotional reactions, varying in intensity, and involving both pleasant and unpleasant affect (Lang et al., 1997). For instance, skin conductance responses are larger when viewing emotionally arousing (pleasant or unpleasant) pictures, compared to neutral pictures, whereas heart rate varies with affective valence, with more deceleratory heart rate responses elicited when viewing unpleasant,

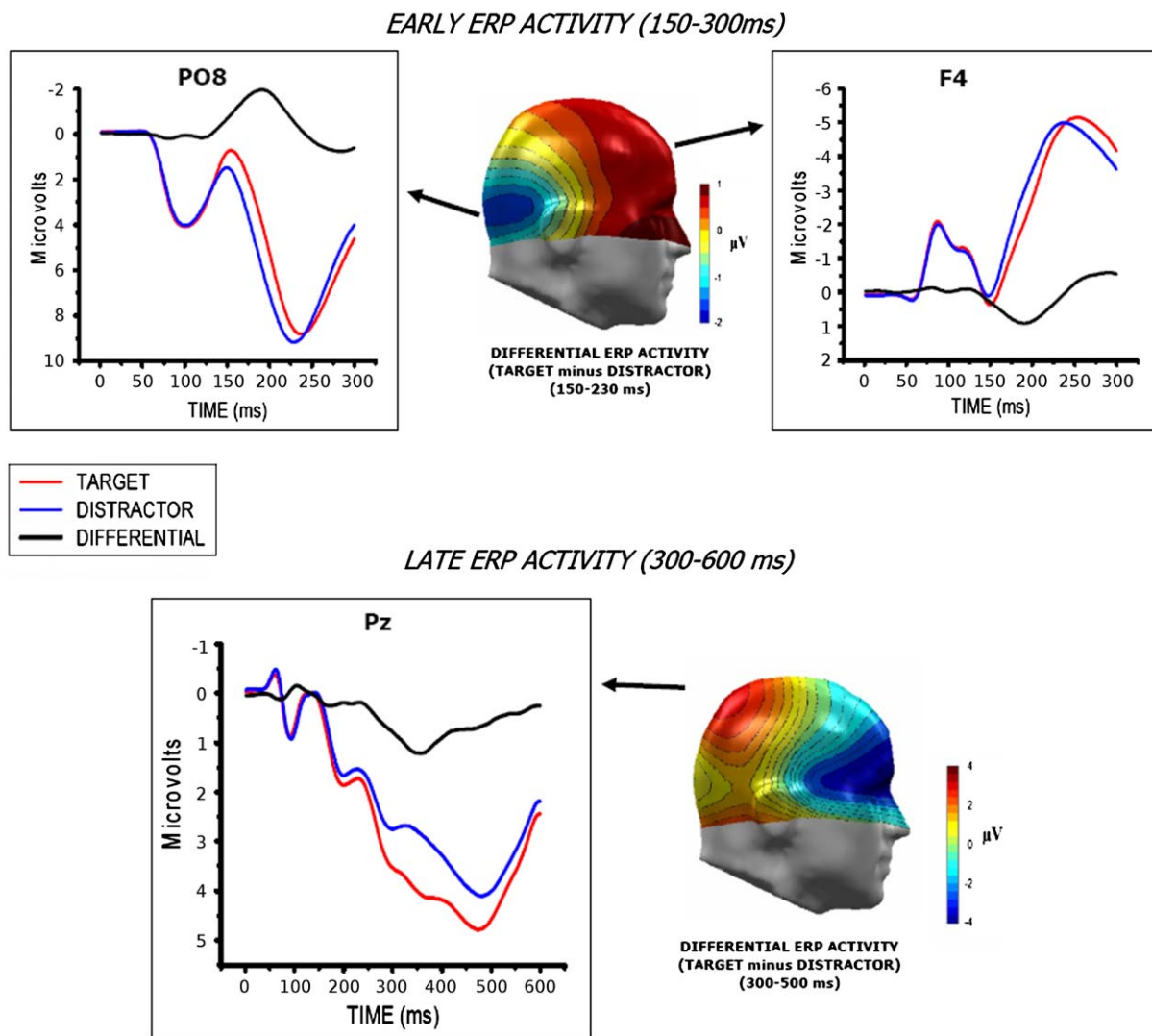


Fig. 1. ERP waveforms showing early brain potentials over occipito-temporal (PO8) and frontal (F4) sites and late positive potentials over a parietal site (Pz) during explicit categorization of natural scenes. Scalp potential maps also reveal the topography of the early and late differential ERP activity (Target minus distractor).

relative to neutral pictures (Bradley et al., 2001). In addition, it has been shown that affective pictures are effective cues in evoking not only autonomic responses but also a broad range of neuroendocrine changes (Codispoti et al., 2003).

The emotional context, elicited by photographic slides, also affects the startle reflex. It is well established that the magnitude of the blink response to a startling acoustic or visual probe varies according to the affective valence of the foreground

picture stimuli (Lang et al., 1990). Specifically, the startle reflex is larger when people view unpleasant rather than pleasant pictures (Vrana et al., 1988; Bradley et al., 2006). Consistent with the motivational hypothesis, it has been shown that the strongest reports of emotional arousal, largest skin conductance responses, and greatest modulation of the startle reflex occurs when participants view pictures depicting threats, mutilated bodies and erotica (Bradley et al., 2001, 2006).

In a number of recent experimental findings, ERPs were shown to be modulated by emotionally significant stimuli. In particular emotionally arousing (pleasant and unpleasant) pictures elicit larger LPPs than neutral stimuli in a window from 400 to 800 ms after picture onset (Cacioppo et al., 1994; Cuthbert et al., 2000; Schupp et al., 2000) and occipital and posterior parietal regions were suggested to be a possible origin of the arousal-modulated late positive wave (Keil et al., 2002). This effect has been linked to the concept of motivated attention, which proposes that motivationally significant stimuli are selectively processed because they naturally engage attentional resources (Lang et al., 1997).

Furthermore, recent studies also found an early selective processing of affective cues, in which emotional pictures prompt less positivity than neutral pictures over occipito-temporal sites starting at 150 ms after picture onset and lasting for about 100 ms (Schupp et al., 2004). The affective modulation of this early time interval has been interpreted as indication that the emotional content of visual cues facilitates the sensory encoding of these stimuli (Schupp et al., 2003).

Moreover, affective modulation of early and late ERP components do not rely on voluntary evaluation of the hedonic content (Cuthbert et al., 1995; Codispoti et al., 1998; Junghoefer et al., 2001; Keil et al., 2002; Schupp et al., 2003). For instance, Cuthbert et al. (1995) compared LPP during passive viewing or when an evaluative rating task was required, and found similar modulation, suggesting that affective evaluation, as measured by the LPP, may be a relatively obligatory process.

These cortical and autonomic changes during affective picture processing are obtained when participants view pictures for a sustained time period (e.g., 6 s). In a series of studies, we investigated whether brief presentations are also able to engage the defensive and appetitive motivational systems that mediate emotional responding (Codispoti et al., 2001, 2002). In particular, pictures were presented briefly for different exposure times (from 25 ms to 6 s) and in one condition were followed by a blank screen (unmasked condition), while in another condition were followed by masking stimulus

(masked condition). The masking stimulus was a scrambled image. In the unmasked condition, affective modulation in terms of subjective and cortical reactions was only slightly affected by the pictures' exposure time, while heart rate modulation appeared to rely on the presence of the stimulus. Moreover, in the masked condition, subjective and cortical reactions were modulated by the affective content of the stimulus even when pictures were presented very briefly (> 50 ms), whereas longer exposure times were needed to observe autonomic changes as a function of picture content. Taken together, these findings indicate that stimulus categorization, reflected in cortical and subjective changes, is elicited even when affective scenes are briefly presented. Differentially, autonomic changes probably reflecting stimulus intake and preparation for action are not activated when the emotional impact of the stimulus is reduced as a consequence of short picture exposure time.

Brief presentation might be considered analogous to a distant (rather than imminent) predator or prey that should determine less intense appetitive and defensive activation leading to less autonomic changes associated with preparation for action (Lang et al., 1997). Consistent with the prediction of larger emotional response to proximal stimuli, a study comparing the reaction of snake-phobic participants to snakes presented at various distances (Teghtsoonian and Frost, 1982) showed a linear increase of autonomic responses and self-reported fear as a function of distance. Since distance and retinal size are strictly related (Loftus and Harley, 2005), it can be expected that changes in stimulus size determine arousal modulations similarly to distance. Moreover, in an evolutionary framework, the physical size of an encountered object or organism may determine the motivational relevance for the observer. This possibility is supported by the results of a recent study (Reeves et al., 1999) which investigated autonomic response following arousing and non arousing stimuli presented in different sizes, suggesting a more pronounced emotional response for bigger stimuli.

Recently, we assessed the possibility that changes in stimulus size may influence the affective

modulation of early and late ERPs (De Cesarei and Codispoti, 2006). Assuming that size reduction determines lower relevance of the scene to the observer, a reduction in affective modulation at both early and late stages of processing was expected for smaller compared to larger images. Alternatively, since size reduction also results in decreased discriminability due to the loss of fine details in the scene (Loftus and Harley, 2005), we expected that the earlier time window, reflecting stages of perceptual analysis, would have been more affected by size reduction compared to the LPP, which is thought to reflect processes initiated after stimulus recognition.

While a decrease in the modulation of the early ERP time interval (150–300 ms) as a function of stimulus content was observed following image size reduction, affective modulation of the LPP did not change as a function of picture size, suggesting that at this stage a semantic, size-invariant representation of the stimulus has been attained (see Fig. 2). Similarly, other studies using explicit categorization tasks have shown that when discriminability of the image is reduced, early modulation in the 150–300 ms latency range is largely reduced (Goffaux et al., 2003; Macè et al., 2005).

Explicit categorization and affective modulation: emotional scenes as distractors

In everyday life, while monitoring the environment, we evaluate the relevant stimuli, even when not explicitly intending to do so. We make such implicit categorization processes in order to understand and encode the context. The process of implicit categorization can be considered as the act of responding differently to objects and events in the environment that belong to separate classes or categories, even when it is not explicitly required.

Recently, we examined whether selective attention underlying categorization based on target features and motivated attention share similar mechanisms and whether emotional modulation of the LPP is reduced when affective stimuli are presented as distractors during an explicit categorization task (Cardinale et al., 2005). Participants performed two categorization tasks in counterbalanced order: in one condition participants were asked to decide if a picture contained an animal or not, and in the other condition they had to decide if the picture contained a human. The stimuli involved three natural scene images: animal, non-living (natural landscape scenes and pictures of

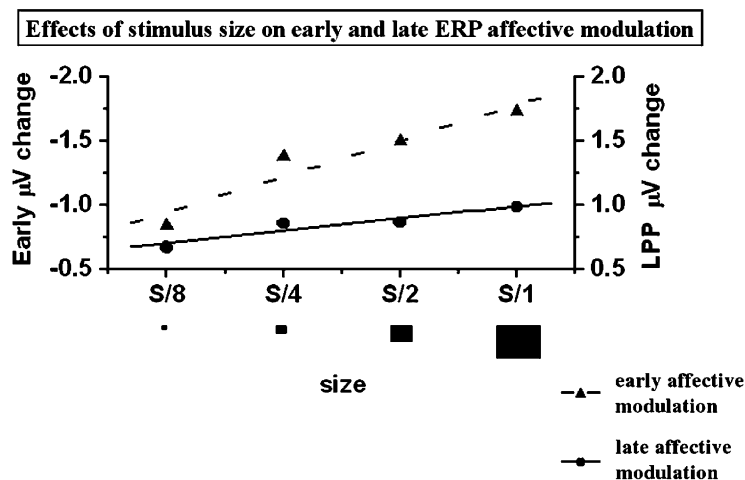


Fig. 2. Early and late ERP affective modulation to pictures presented in different sizes, ranging from smallest (left end) to larger (right end). Labels represent the ratio between the actual and the 100% stimulus size. Horizontal and vertical angles subtended by images are $3^\circ \times 2^\circ$ (S/8), $5^\circ \times 4^\circ$ (S/4), $11^\circ \times 8^\circ$ (S/2) and $21^\circ \times 16^\circ$ (S/1).

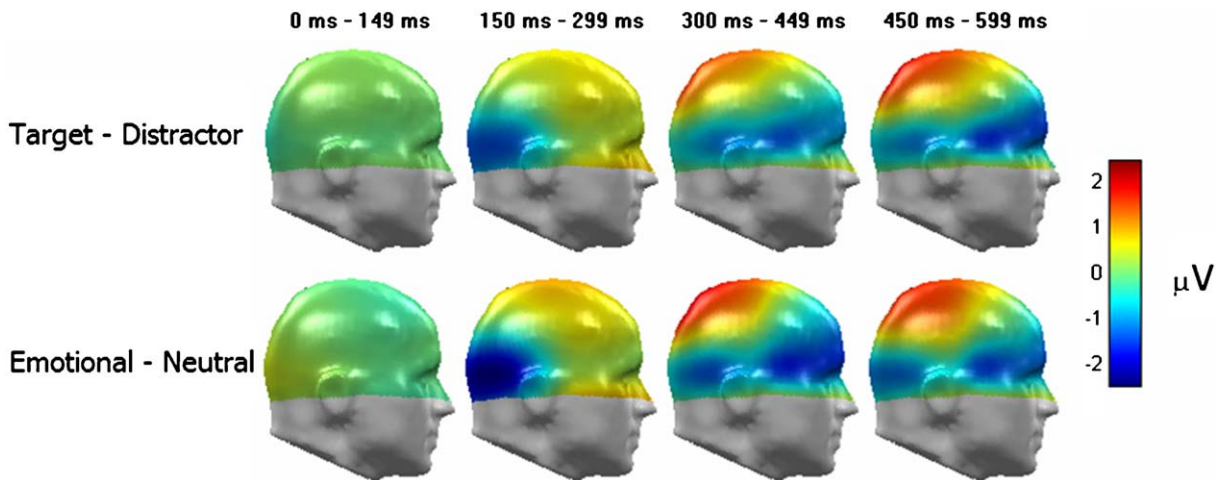


Fig. 3. Scalp potential maps reveal similar topographies of the early and late differential ERP activity during an explicit categorization task as well as during the perception of emotional non-target stimuli (animal target condition). Bilateral foci of occipito-temporal negativity appeared for the differential ERP activity in the time window from 150 to 300 ms. Later in the classical P3 window 300–600 ms, target as well as emotional pictures elicit a larger positive potential compared to distractor and neutral images, which is maximally pronounced over centro-parietal sensor sites. Illustrated is the right side view of the model head.

objects) and human (erotic couples, neutral people, mutilated bodies).

Results seem to suggest that regardless of the cause of relevance of a stimulus, whether it be task relevant (Target) or inherently significant (emotional), similar cortical changes are involved (see Fig. 3). Also, affective modulation of the LPP persisted even when these stimuli (human pictures) were distractors (animal target condition). Specifically, when animal pictures were the target, they elicited a larger LPP compared to neutral people and this positivity did not differ from the one determined by emotional stimuli, suggesting that selective attention on target features and motivated attention share similar neural mechanisms (see Fig. 3).

Interestingly, in this study the task did not affect ERP responses to animal pictures in the early time interval (150–300 ms), in which similar early brain potentials were observed across the two conditions (animal task and human task). This finding was interpreted as a consequence of the similarities between the two target categories in terms of features of intermediate complexity and is consistent with recent evidence from Evans and Treisman (2005), discussed above, showing that detection of target in a RSVP study was considerably worse in sequences that also contained humans as distractors.

These findings seem to indicate not only that affective modulation of the LPP does not depend on the evaluative nature of the task, but that is present even when participants were asked to perform a categorization task where pleasant, neutral and unpleasant images were distractors. Although these studies suggest that emotional pictures are automatically categorized and capture attentional resources, it should be noted that in these studies not only was the competing task undemanding, but the pictures had to be perceived and categorized in order to establish if they belonged to the target category or not.

Pessoa and co-workers (Pessoa and Ungerleider, 2004; Pessoa et al., 2005) have shown that the processing of emotional visual stimuli might be modulated by the availability of attentional resources. In a recent fMRI study, central faces with neutral or fearful expression were presented centrally along with peripheral bars. During the bar-orientation task, subjects were asked to indicate whether the orientation of the bars was the same or not and the difficulty level of the task was manipulated according to the angular difference of the bars, in order to investigate the effect of attentional resources on emotionally relevant distractor stimuli. The results showed that in the

amygdala, differential responses to fearful faces compared to neutral faces were observed only during low-load conditions. This findings seem to be consistent with Lavie's (1995; Lavie et al., 2004) proposal that if the processing load of a target task exhausts available capacity, stimuli irrelevant to that task will not be processed.

Similarly in a recent experiment, we manipulated the perceptual load of a competing task to evaluate to what extent emotional stimuli are automatically categorized as a function of available resources. In this study, participants were presented a picture (pleasant, neutral and unpleasant) in the left or right hemifield for 100 ms while simultaneously performing a foveal task where they were asked to detect an X or a Z presented alone (low perceptual load condition) or flanked by other letters (high load condition). Results indicated that early (150–300 ms) modulation of the ERP over occipito-temporal regions was affected by the perceptual load of the foveal task. In fact, while emotional pictures elicited less positivity compared to neutral pictures in the low perceptual load condition, this differential activity disappeared in the high perceptual load condition. On the other hand, the late positive potential was unaffected by the foveal task suggesting that the LPP might index a post-perceptual stage of processing and that even in a highly demanding condition emotional content of the picture is processed by the brain.

Interestingly, as discussed above, similar results were found when the size of the images was manipulated (De Cesare and Codispoti, 2006). In fact, picture size affected the modulation of the early ERP time interval (150–300 ms) as a function of stimulus content, while affective modulation of the LPP did not change as a function of picture size.

Taken together, these findings suggest that the affective modulation of the LPP, probably related to post-perceptual stages of processing, is not influenced by perceptual factors, persists even when pictures are presented as distractors and attention is manipulated by a demanding task (participants were engaged in a demanding competing task). By contrast, two different perceptual factors (the perceptual load of a competing task and picture size) affect the modulation of the early ERP time

interval (150–300 ms) as a function of stimulus content over occipito-temporal regions.

Affective modulation and habituation

These previous findings seem to indicate that the affective modulation of the ERPs is an automatic process that does not rely on voluntary evaluation of the hedonic content of the stimulus.

Along with this reasoning, several behavioural studies have found involuntary semantic processing of affective stimuli (Pratto and John, 1991; Stenberg et al., 1998; McKenna and Sharma, 2004). Moreover, behavioural studies (Bargh et al., 1996; Hermans et al., 2001) have shown that in a priming paradigm, emotional pictures speed up the response when prime and target share the same valence as compared to trials in which prime and target are of opposite valence. Similar findings have been observed also in the absence of an explicitly evaluative context by having participants merely pronounce or make a lexical decision, rather than evaluate target words after briefly viewing picture primes (Wentura, 1998; Giner-Sorolla et al., 1999; for different findings see Storbeck and Robinson, 2004).

One important feature of an obligatory process is resistance to habituation. There is considerable evidence that prior exposure to a stimulus affects subsequent attentional processes and orienting response (Sokolov, 1963; Siddle, 1991; Bradley and Lang, 2000), influences perceptual facilitation associated with “neural suppression” (Tulving and Schacter, 1990; Henson and Rugg, 2003), and leads to changes in subjective ratings of pleasantness and arousal (Fechner, 1876; Zajonc, 1968; Bornstein, 1989; Raymond et al., 2003; Codispoti et al., 2006a). Although a single repetition of a stimulus facilitates subsequent recognition (e.g., repetition priming), with increasing repetitions the salience of the stimulus is reduced. Thus, habituation can be defined as an unlearned behavioural process that results in a diminution of response (i.e., decreased response magnitude and/or increases in response latency) to stimuli that are repeatedly presented (Harris, 1943; Thompson and Spencer, 1966).

Habituation of affective modulation has been investigated for the first time by Bradley and colleagues (1993). In this experiment the same pleasant, neutral and unpleasant picture stimuli were repeatedly presented (12 repetitions for each picture). Startle reflex habituation was assessed and compared with the habituation patterns of autonomic responses (heart rate and skin conductance). Results indicated that whereas all responses showed general habituation over trials, affective modulation of the blink reflex was not affected by picture repetition. As found in previous studies, the blink response was potentiated when startle probes were presented during processing of unpleasant pictures (relative to neutral stimuli) and reduced when viewing pleasant pictures, and this pattern persisted even after several repetitions of the same stimulus.

Recently, we examined the affective modulation of the late positive potential as it varied with stimulus repetition (Codispoti et al., 2006a). Pleasant, neutral and unpleasant pictures were presented up to 60 times. If the LPP reflects automatic affective evaluation, we expected no difference in the modulation of this component across stimulus repetitions. We expected that the autonomic responses (heart rate and skin conductance) would habituate rapidly, providing evidence that the affective impact of the stimulus was maximal early within the habituation phase. Results showed that, although the amplitude of the late positive potential during picture viewing declined with stimulus repetition, affective modulation remained intact. On the other hand, autonomic responses habituated rapidly with stimulus repetition (see Fig. 4). These findings suggest that stimulus repetition does not change the associative strength of connections to subcortical motivational systems, as reflected in the LPP, but does change the output to systems involved in orienting and action.

In this study, measurement of a relatively sparse electrode array (3 sensors) did not provide an opportunity to assess how picture repetition affects the early ERP component over frontal and occipital sites, or whether picture repetition differentially affects early and late ERP components that vary with picture emotionality. Also in this previous study, one factor that might have encouraged

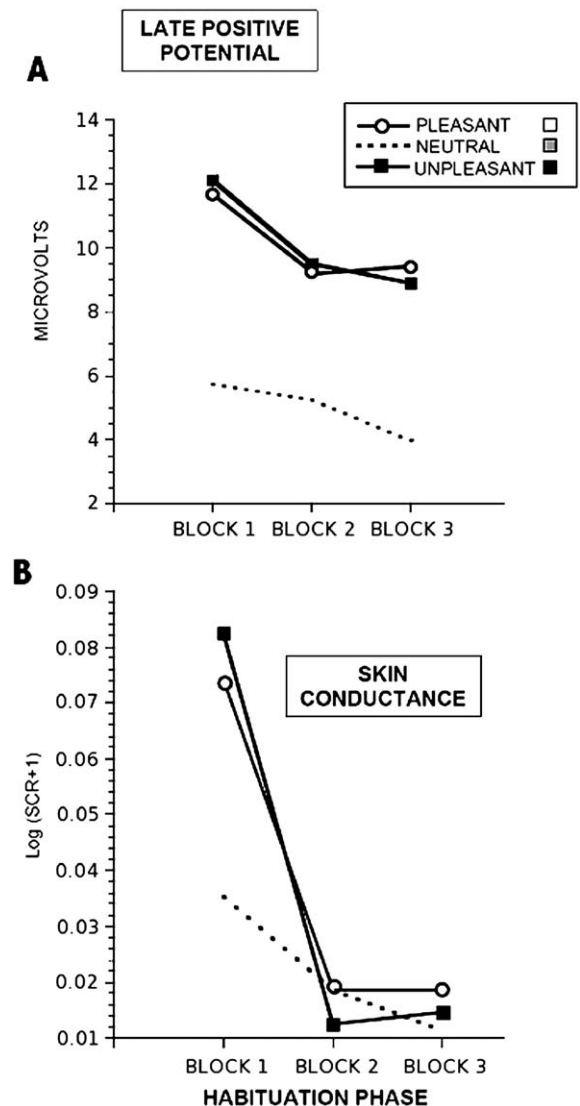


Fig. 4. Late positive potential amplitude (Pz; 400–800 ms (A)) and skin conductance (B) changes elicited when viewing pleasant, neutral and unpleasant pictures during each of the three blocks within the habituation phase.

sustained processing of each stimulus was the use of a relatively long inter-picture interval (e.g., 10–20 s), which may have increased the “novelty” of each picture, despite its continued repetition.

Thus, we decided to further investigate affective habituation in a new study, employing a dense sensor electrode array to assess early and late ERP components as they varied with repetition of affective

tive pictures and using a shorter inter-stimulus interval (2–3 s) to reassess the effects of picture repetition on the late positive potential (Ferrari et al., 2005). This array allowed us to assess ERPs measured over both the occipital and frontal cortex in order to assess the early ERP differences reported in previous studies, as well as to assess once more the late positive potential, which is maximal over centro-parietal sites. Consistent with previous data (Codispoti et al., 2006a) emotionally arousing stimuli continued to prompt larger LPPs than neutral pictures, regardless of repetition. Nonetheless, the magnitude of the late positive potential decreased somewhat for both pleasant and unpleasant pictures following multiple repetitions. On the other hand, there were no effects of repetition on ERPs measured in the earlier time window, suggesting that early effects of emotional arousal may reflect a stimulus-driven process that occurs automatically.

Recently, Schupp and colleagues (2006) showed similar findings using a rapid visual presentation where pictures were presented for 330 ms without an inter-stimulus interval further confirming that the early affective modulation of the ERP over occipito-temporal region is resistant to habituation even in a condition where pictures are presented without an inter-picture interval. Interestingly, using an explicit categorization task, Fabre-Thorpe and co-workers showed that repetitive presentation of natural scenes (14 days over 3 week period) did not facilitate information processing. That is, the early (150 ms) differential ERP effect indicated that the visual processing was just as fast with completely novel images as it was for images with which the subjects were highly familiar (Fabre-Thorpe et al., 2001).

Since in our previous affective habituation studies participants were only asked to look at the pictures, without an additional task, however, we cannot effectively rule out the possibility that affective modulation of the LPP results from a process in which more attention is voluntarily allocated to viewing affective pictures. A strategy for determining whether affective modulation of the LPP and its resistance to habituation is due to obligatory or voluntary processes would be to present affective pictures when participants are

engaged in a competing task. This issue was further investigated in a recent experiment (Biondi et al., 2005) where a picture flanked by two numbers was presented for 150 ms and participants were asked to decide whether the two numbers had the same parity, while ignoring the image. Results suggest that reaction times were markedly longer for arousing pictures, compared with those which were neutral, pictures, but after several repetitions of the same stimuli this effect vanished. Despite the fact that attention is occupied in a competing task, affective modulation of the early and late ERP components persisted even after several repetitions of the same stimulus suggesting that categorization of unattended affective stimuli is an obligatory process that continues to occur whenever a sensory stimulus is presented.

Summary and future directions

Event-related potentials measured during picture viewing vary with emotional arousal, with affective (either pleasant or unpleasant), compared to neutral, pictures eliciting a larger LPP in the 300–600 ms time interval over centro-parietal regions. This component has been interpreted as reflecting enhanced attention to motivationally relevant pictures. In addition, an early ERP component was also reported to vary with emotional arousal in a window from about 150 to 300 ms, with affective, compared to neutral, stimuli, prompting significantly less positivity over occipito-temporal sites. Similarly, in explicit categorization tasks of complex natural scenes, the activity of target and non-target ERPs diverged sharply around 150 ms after stimulus onset and this early differential ERP activity (target minus non-target) appeared as negative deflection over occipito-temporal regions. Furthermore, in a time interval 300–600 ms after stimulus onset, target scenes were associated with augmented LPP over centro-parietal sites suggesting that similar mechanism are involved in selective attention to target features and to motivationally relevant stimuli.

Several studies have shown that the affective modulation of the LPP persisted even when the same pictures are repeated several times, when

they are presented as distractors or when participants are engaged in a competing task, indicating that categorization of affective stimuli is an obligatory process. On the other hand, while the affective modulation of the LPP is not influenced by perceptual factors (e.g., stimulus size), these same factors strongly reduce the modulation of the early ERP time interval (150–300 ms) as a function of stimulus content. Although early and late ERP components vary with stimulus relevance, given that they are differentially affected by stimulus and task manipulations, they appear to reflect different sensory and attentional processes. Future studies should further investigate functional and neural mechanisms underlying natural scene categorization, and examine how and when motivational systems (e.g., appetitive and defensive) modulate the processing of stimulus features. Further work should also better clarify the nature of the perceptual features that affect early stages of processing in picture perception.

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