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# The influence of color on emotional perception of natural scenes

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**Abstract**

Is color a critical factor when processing the emotional content of natural scenes? Under challenging perceptual conditions, such as when pictures are briefly presented, color might facilitate scene segmentation and/or function as a semantic cue via association with scene-relevant concepts (e.g., red and blood/injury). To clarify the influence of color on affective picture perception, we compared the late positive potentials (LPP) to color versus grayscale pictures, presented for very brief (24 ms) and longer (6 s) exposure durations. Results indicated that removing color information had no effect on the affective modulation of the LPP, regardless of exposure duration. These findings imply that the recognition of the emotional content of scenes, even when presented very briefly, does not critically rely on color information.

**Descriptors:** Emotion, Motivation, EEG/ERP, Categorization, Orienting

The human recognizes objects very rapidly, even when those objects are presented in complex scenes and amidst perceptual and cognitive challenge (Grill-Spector & Kanwisher, 2005; Kirchner & Thorpe, 2006; Potter & Levy, 1969). This extraordinary capacity provides an evolutionary advantage, as our perceptual system serves the adaptive function of identifying an object or individual as a potential threat or reward, in order to act appropriately.

One of the most well-established findings in the literature on affective picture processing is that emotionally arousing (pleasant and unpleasant) pictures elicit a larger late positive potential (LPP) than neutral pictures (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Johnston, Miller, & Burleson, 1986; Radilova, 1982; Schupp, Cuthbert et al., 2004), which seems to reflect both the engagement of attentional resources by emotional stimuli and the activation of cortico-limbic appetitive and defensive systems, to facilitate perception and ultimately promote adaptive behavior (Bradley, 2009; Codispoti, Ferrari, & Bradley, 2007; Lang, Bradley, & Cuthbert, 1997). Underscoring the robustness of this finding, the sensitivity of the LPP to emotional arousal is maintained despite competing cognitive tasks (Codispoti, Ferrari, De Cesarei, & Cardinale, 2006; Hajcak, Dunning, & Foti, 2007; Wangelin, Löw, McTeague, Bradley, & Lang, 2011) and even subsequent to massive repetition (Codispoti et al., 2007; Ferrari, Bradley, Codispoti, & Lang, 2011).

Recent studies have demonstrated that these emotional cues also persist in modulating the LPP even under perceptually challenging conditions in which the stimuli are relatively degraded with a very small visual angle ($3° \times 2°$; De Cesarei & Codispoti, 2011), presentation in the periphery of the visual field (8° of eccentricity, De Cesarei, Codispoti, & Schupp, 2009), or very brief exposure duration (25 ms; Codispoti, Mazzetti, & Bradley, 2009; Ferrari, Codispoti, Cardinale, & Bradley, 2008).

However, much less is known regarding the influence of color on the affective modulation of LPP during perception of natural scenes. Is color a critical factor in the process of recognizing the emotional content of natural scenes? Does color information contribute to the emotional response? One might hypothesize that color would play a critical role in picture perception and emotional engagement especially under perceptually challenging conditions, when visual information is partially degraded. In fact, color could facilitate scene segmentation, and/or directly function as a thematic cue owing to association with specific scene concepts in memory (e.g., red color signals blood/injury). Since global properties decisively inform scene identification of briefly presented pictures (Schyns & Oliva, 1994), and the color of foreground objects is a global property (Castelhano & Henderson, 2008), the extraction of color may be crucial for emotional perception—even more pronounced for very briefly presented pictures.

Building on the assumption that color is a contributing factor in the affective modulation of event-related potentials (ERPs) and that color is associated with emotion intensity, in a recent study Cano, Class, and Polich (2009) examined the effect of picture color using a long picture presentation (1 s). No affective modulation of ERPs was evident in response to black-and-white pictures, leading the authors to conclude that stimulus color is critical in the affective

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modulation of ERPs (Cano et al., 2009). However, this study suffers from a serious methodological limitation; namely, emotional and neutral pictures were equivalent in terms of arousal ratings, and, in fact, the authors similarly found no affective modulation of the LPP in the color condition, necessarily undermining the interpretation that the null effects were secondary to the absence of color. Cano and colleagues' interpretation is also inconsistent with a study by Weymar, Löw, Melzig, and Hamm (2009), who reported no effect of picture color on the affective modulation of the LPP using a long picture presentation, and a between-subject design. Nevertheless, it may well be that, especially under degraded visual conditions, picture color plays a role in modulating affective responses to natural pictures, either by facilitating scene segmentation or by cueing specific contents.

The goal of the present study was to clarify the influence of color on affective picture perception in a within-subjects design. As such, we compared the LPP to color and black-and-white pictures presented for a longer presentation (6 s), to enable comparison with the preponderance of existing studies, as well as a very brief (24 ms) exposure duration, to examine whether color sensitivity might be more evident under a relatively degraded perceptual condition.

## Methods

### Participants

Participants were 16 students (eight women), from the University of Bologna with normal or corrected-to-normal visual acuity. Informed consent was obtained from each participant prior to the experiment.

### Stimuli and Equipment

Stimuli were 180 pictures—60 pleasant, 60 neutral, and 60 unpleasant—selected from various sources, including the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), public domain pictures available on the Internet, and from document scanning. Within these picture categories, contents were varied and included erotic couples, opposite sex nudes, romantic couples, people in neutral contexts, human threat scenes, and mutilated bodies. Two versions of each picture were created, one in color (32-bit) and one in grayscale (8-bit). For each participant, half of the pictures ($n = 90$) were presented in color and half in black and white. For each of these two conditions, half of the pictures were presented for 6 s and half for 24 ms. Therefore, the experiment consisted of four conditions: color pictures presented for 6 s, color pictures presented for 24 ms, black-and-white pictures presented for 6 s, and black-and-white pictures presented for 24 ms. Pleasant, neutral, and unpleasant pictures were equally distributed in each condition. Across the whole group of participants, each picture was shown in all four conditions (color and black and white, and for 6 s or 24 ms). Stimuli were presented on a 21″ CRT monitor placed 1 m away from the participant, at 800 × 600 pixel resolution and 85 Hz refresh rate, subtending 22.6° horizontal × 17.1° vertical degrees of visual angle. Sixteen different presentation sequences were built by permuting image order with the constraint that no more than three consecutive images depicting the same content were presented in any one of the four conditions. All pictures were equated in brightness and contrast (155 and 25 on a scale ranging from 0–255) and pasted on a gray background. The gray background had a brightness of 155 on a 0–255 RGB scale. The experiment was run using E-Prime (Schneider, Eschman, & Zuccolotto, 2002).

### Procedure

Following informed consent, sensors were attached and the participant was instructed that a series of pictures would be presented, either briefly or for a longer duration. Participants were instructed to comfortably maintain fixation on a central point throughout the study.

During each trial, a fixation cross was presented for 1 s. After this time, an image was displayed and remained visible for 6 s or 24 ms. Seven seconds from image onset, the visual rating scales of valence and arousal were presented using the Self-Assessment Manikin (SAM; Lang, 1980). After the ratings, a blank interval lasting between 2 and 3 s was presented (intertrial interval, ITI).

### EEG Recording and Processing

The electroencephalogram (EEG) was recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands). EEG was recorded with a 256 dense sensor array (see supplementary material), with 256 Hz of sampling rate. The EEG was referenced to an additional active electrode (CMS = common mode sense; with ground in additional electrode DRL = driven right leg) during recording. All data were rereferenced to the average of all scalp electrodes and low-pass filtered with cutoffs of 40 Hz. Additionally, a sensor was attached below the left eye. For each trial, EEG was corrected for blinks and eye movements using a regression technique based on the electrodes above and below the left eye, and left and right to the side of the eyes (Schlögl et al., 2007). Off-line analysis was performed using EMEGS (Peyk, De Cesarei, & Junghöfer, 2011), and included artifact detection and sensor interpolation (Junghöfer, Elbert, Tucker, & Rockstroh, 2000). On average, 80.09% (range 74.43%–85.41%) of total trials were included in each average. For each condition, an average of 12 (range 11.12–12.8) good trials from each participant were selected.

### Data Analysis

A baseline correction based on the 100 ms prior to picture onset was performed. Averaged ERP waveforms were calculated for each participant and experimental condition. After examination of the ERP waveforms and topography, the statistical analyses were conducted in the time window between 400 and 800 ms over recording sites (occipito-parietal areas; (see cluster of sensors in Figure S1 of the supporting information) where the LPP amplitude was largest (Picton et al., 2000).

A repeated measures ANOVA was conducted on subjective ratings (valence and arousal) and LPP with Picture Color (2 levels: color and grayscale), Exposure Duration (2 levels: 6 s and 24 ms) and Picture Category (3 levels: pleasant, neutral, unpleasant) as within-subjects factors. Huynh–Feldt correction was used when appropriate. The partial eta squared statistic ($\eta_p^2$), indicating the proportion between the variance explained by one experimental factor and the total variance, has been calculated and is reported.

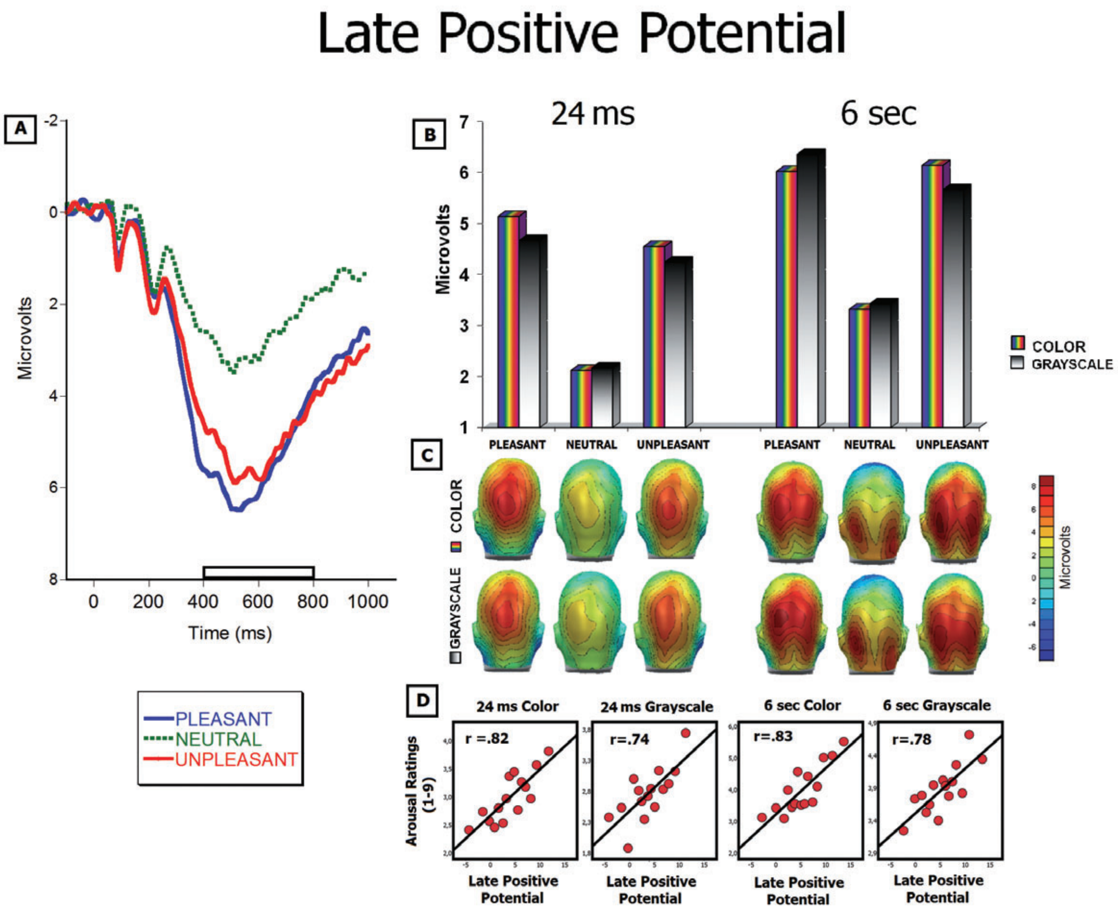


**Figure 1.** The effects of picture color and exposure time on affective modulation of the LPP. (A) ERPs at occipito-parietal sensor sites for pleasant, neutral, and unpleasant scenes, averaged across the four experimental conditions. (B) The effects of picture content, color, and exposure time on the average LPP amplitude in the 400–800 ms time interval. (C) Scalp maps (back view) of the LPP amplitude, separately for each picture content, picture color, and exposure time. (D) Scatterplots of the relationship between LPP amplitude and SAM arousal ratings, in each of the four conditions.

## Results

### Event-Related Potentials[1]

The LPP amplitude was modulated by Picture Content, $F(2,30) = 40.1$, $p < .001$, $\eta^2_p = .73$, with a larger occipito-parietal positivity for both pleasant and unpleasant, compared to neutral pictures, $F(1,15) = 69.8$, $p < .001$, $\eta^2_p = .82$ (see Figure 1A). LPP amplitude to pleasant and unpleasant pictures did not differ, $F(1,15) < 1$. No interactions of Picture Color and Exposure Duration factors with Picture Content were found, showing that the LPP was similarly affected by picture content in all four conditions, $F_s(1,15) > 19.1$, $p_s < .001$, $\eta^2_{ps} < .56$ (see Figure 1B and 1C). A main effect of Exposure Duration, $F(1,15) = 13.9$, $p < .001$, $\eta^2_p = .48$, indicated that the LPP magnitude was larger for pictures shown for the longer (6 s) as opposed to very brief exposure duration (24 ms). Figure 1D illustrates the high correlation between the LPP and arousal ratings, which was equivalent in all four conditions.[2]

Additionally, we assessed the positive slow wave (Cuthbert et al., 2000) after the LPP component, over the same sensors. This slow wave was scored by mean activity in successive 500 ms bins from 1 to 6 s time. Pleasant and unpleasant pictures elicited a larger sustained positivity compared to neutral stimuli until 5000 ms in all intervals, Picture Content $F_s(1,15) > 4.4$, $p_s < .05$, $\eta^2_{ps} > .22$. Also, an effect of picture exposure was found in all 500 ms intervals,

1. Further analyses were conducted to evaluate the effects of Color, Exposure Duration, and Picture Content on an early time interval (150–300 ms) over occipito-temporal regions (EPN, early posterior negativity; Schupp, Junghöfer, Weike, & Hamm, 2004; Schupp et al., 2007) (see cluster of sensors in Figure S2 of the supporting information). Results indicated a main effect of Picture Content on the early time interval (150–300 ms), $F(2,30) = 95.5$, $p < .001$, $\eta^2_p = .86$: Pleasant and Unpleasant pictures elicited less positivity than neutral stimuli, $F(1,15) = 213.2$, $p < .001$, $\eta^2_p = .93$, and pleasant pictures elicited less positivity compared to unpleasant pictures, $F(1,15) = 47.2$, $p < .001$, $\eta^2_p = .76$. No interactions of Picture Content with Exposure Duration, Picture Color, or both, were observed. These findings are consistent with a previous study (Junghöfer, Bradley, Elbert, & Lang, 2001), which examined affective modulation of the EPN using a rapid presentation and a between-subject design.

2. To calculate the correlation between the LPP and self-reported arousal, the following procedure was adopted. Within each participant and color/exposure duration condition, single-trial ERPs were classified in 15 ranks based on the absolute ERP amplitude over the occipito-parietal sensors in the 400–800 ms time interval. Single-trial LPP amplitude and SAM arousal ratings from the whole sample of participants were then aggregated in the conditions defined by the within-subjects LPP rank and the four degradation conditions. Based on these data, the correlation between the LPP and self-reported arousal was calculated.

**Table 1.** *Mean Ratings of Arousal and Valence for Each Condition*

| | Pleasant pictures | | | | Neutral pictures | | | | Unpleasant pictures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Color | | Grayscale | | Color | | Grayscale | | Color | | Grayscale | |
| | 6 s | 24 ms | 6 s | 24 ms | 6 s | 24 ms | 6 s | 24 ms | 6 s | 24 ms | 6 s | 24 ms |
| SAM valence | 6.73 (.71) | 6.36 (.62) | 6.88 (.68) | 6.19 (.59) | 5.76 (.34) | 5.31 (.29) | 5.65 (.33) | 5.22 (.26) | 2.55 (1.10) | 3.48 (.98) | 2.64 (1.09) | 3.67 (.96) |
| SAM arousal | 4.14 (1.91) | 3.30 (1.81) | 4.30 (1.96) | 3.17 (1.54) | 2.51 (1.17) | 1.90 (1.06) | 2.44 (1.27) | 1.85 (.99) | 5.23 (2.10) | 3.47 (1.71) | 4.89 (1.88) | 3.07 (1.48) |

*Note*. Standard deviations are in parentheses.

$F(1,15) > 6.07$, $p_s < .05$, $\eta^2_{ps} > .28$, showing a larger slow positive wave for pictures presented for 6 s, compared to pictures presented for 24 ms. Again, as for the LPP, no interactions of Exposure Duration and Picture Color with Picture Content were found.

## Evaluative Judgments

**Pleasure rating.** The main effect of Picture Content was significant, $F(2,28) = 80.9$, $p < .001$, $\eta^2_p = .85$. As reported in Table 1, in all four conditions, pleasant, neutral, and unpleasant pictures were rated as different in pleasure, $F_s(2,28) > 42.4$. $p_s < .001$, $\eta^2_{ps} > .75$. An interaction of Picture Content and Exposure Duration, $F(2,28) = 72.8$, $p < .001$, $\eta^2_p = .84$, indicated that the difference between pleasant and unpleasant pictures was larger in response to the longer duration (6 s) compared to a brief exposure (24 ms), $F(1,14) = 76.5$, $p < .001$, $\eta^2_p = .84$. Finally, a significant interaction between Picture Content and Picture Color was observed, $F(2,28) = 4.9$, $p < .05$, $\eta^2_p = .26$, indicating that unpleasant pictures were rated as more unpleasant when presented in color than when presented in black and white, $F(1,14) = 4.9$, $p < .05$, $\eta^2_p = .25$ (color $M = 3.01$, $SD = 1$; grayscale $M = 3.15$, $SD = .98$). The three-way interaction Picture Content × Exposure Duration × Picture Color was not statistically significant, $F(2,28) = 2$.

**Arousal rating.** The main effect of Picture Content was significant, $F(2,28) = 25.6$, $p < .001$, $\eta^2_p = .65$. Pleasant and unpleasant pictures were rated as more arousing than neutral pictures, $F(1,14) = 37.4$, $p < .001$, $\eta^2_p = .73$, and did not differ from each other $F(1,14) = 3.2$, $p > .05$ (see Table 1). An interaction of Picture Content and Exposure Duration, $F(2,28) = 17.9$, $p < .001$, $\eta^2_p = .56$, indicated that the difference between arousing (pleasant and unpleasant) and neutral pictures was amplified by the long exposure duration compared to a brief exposure, $F(1,14) = 14$, $p < .005$, $\eta^2_p = .50$, see Table 1. Finally, a significant interaction between Picture Content and Picture Color, $F(2,28) = 5.3$, $p < .05$, $\eta^2_p = .27$, indicated that unpleasant pictures were rated as more arousing when presented in color than when presented in black and white, $F(1,14) = 6.7$, $p < .05$, $\eta^2_p = .33$ (color $M = 4.35$, $SD = 1.86$; grayscale $M = 3.98$, $SD = 1.65$). The three-way interaction Picture Content × Exposure Duration × Picture Color was not statistically significant, $F(2,28) < 1$.

## Discussion

In this study, we assessed whether color contributes to the affective modulation of ERPs during the perception of natural scenes presented very briefly or with longer presentation duration. The main result of the present study was that color had no influence on the affective modulation of the late positive potential and, moreover, even when pictures were briefly presented.

Replicating previous studies (Codispoti et al., 2009; Ferrari et al., 2008), a larger LPP for emotional (both pleasant and unpleasant), compared to neutral, pictures was found when pictures were either presented for long exposure duration (6 s) or for only 24 ms, confirming that the LPP affective modulation does not rely on picture exposure time in unmasked conditions. Furthermore, even when visual processing is somehow degraded as pictures were only transiently presented, a similar affective modulation of the LPP was observed between colored and black-and-white images, ruling out the hypothesis that recognition of picture emotional content, especially under challenging conditions, might be accomplished solely by using color for picture segmentation, and/or as a cue for scene gist owing to its specific association with particular scene concept in memory (e.g., *flesh color* for erotic pictures). These results were further confirmed by the correlation analyses between the late positive potential and arousal subjective ratings, which showed similar highly significant coefficients in all conditions (see Figure 1D), excluding the possibility that the observed effects are due to confounds (e.g., spatial frequencies), which may be present for some categories (Pernet, Schyns, & Demonet, 2007), but it is very unlikely that a potential confound varies along a continuum (i.e., arousal dimension). Altogether, the results of the present study are consistent with previous research indicating that the affective modulation of the LPP is not due to bottom–up perceptual factors, such as picture size, complexity, or spatial frequencies (Bradley, Hamby, Löw, & Lang, 2007; Codispoti et al., 2006; De Cesarei & Codispoti, 2011; Ferrari, Bradley, Codispoti, & Lang, 2010), but instead it relies on the recognition of the emotional content of the stimuli (Codispoti et al., 2009).

A previous study by Cano and colleagues (2009) explored the impact of color on emotional response, and since they did not observe any modulation of the P300/LPP when emotional pictures were presented in black and white, the authors concluded that color is a critical factor in the emotional ERP effects reported in the literature. However, this conclusion is problematic as Cano and colleagues also failed to find the P300/LPP emotional modulation for pictures in color (in two different experiments), rendering futile the comparison between color and black-and-white pictures in the P300/LPP amplitude modulation. Since the larger positivity for arousing pictures (pleasant and unpleasant), compared to neutral stimuli, over posterior brain sites is a reliable effect reported in several studies across laboratories (De Cesarei & Codispoti, 2011; Lang & Bradley, 2010; Schupp, Junghöfer, et al., 2004; Weinberg & Hajcak, 2010), a likely and parsimonious explanation for the failure to observe this effect in the color condition is the inclusion of picture contents known to only weakly activate the motive systems reflected in the LPP modulation (Cuthbert, et al., 2000; Schupp, Cuthbert, et al., 2004).

Consistent with the LPP findings of the present study, earlier investigations, using long picture presentations, have shown that central (Bradley et al., 2003; Sabatinelli, Bradley, Lang, Costa, & Keil, 2009; Weymar et al., 2009) and peripheral (Bradley, Codispoti, Cuthbert, & Lang, 2001; Detenber, Simons, & Reiss, 2000) responses of emotional engagement are similarly affected by stimulus content whether pictures are presented in color or in grayscale. In the same way, heightened resource allocation during affective picture processing does not seem to depend on picture color, as reaction times to secondary probes are slower during viewing of emotional compared to neutral pictures, whether presented in color or black and white (Bradley, Cuthbert, & Lang, 1999; De Cesarei & Codispoti, 2008; Verbruggen & De Houwer, 2007). Also, in terms of subjective ratings, a previous study observed similar effects of specific picture content, regardless of picture color (Bradley et al., 2001; Detenber et al., 2000). Consistently, in the present study, arousal and valence ratings were remarkably similar in color and black-and-white conditions; only unpleasant pictures were rated as slightly less unpleasant and arousing when presented in grayscale, compared to the same pictures in color, regardless of exposure duration. Although statistically significant, these effects for unpleasant stimuli were very small in terms of differences between the two conditions, namely 0.14 for valence and 0.37 for arousal ratings (on a scale from 1 to 9), suggesting that, consistent with previous studies, the impact on subjective experience is due to the recognition of the emotional content of the picture with little room for modulation by perceptual factors such as color, picture size, or blurring (Codispoti & De Cesarei, 2007; De Cesarei & Codispoti, 2008).

Although most studies on natural scene categorization have used only color images, some have assessed the effect of color information on scene recognition. Using a rapid categorization task, where participants were asked to detect a target (animal/nonanimal) in briefly (32 ms) flashed images, several studies showed that colored and grayscale images produced a very similar pattern in terms of reaction times as well as recognition accuracy (Delorme, Richard, & Fabre-Thorpe, 2000; Fei-Fei, VanRullen, Koch, & Perona, 2005; Rousselet, 2005), suggesting that, as in the present study, rapid scene categorization does not depend on the color information. However, in these previous categorization studies, detection of a specific target category (e.g., animals vs. all other contents) relies heavily on some sort of priming where detection results from the matching of a top–down template with bottom–up information, maximizing the categorization efficiency (Enns, 2004). In contrast, in the current study, given the highly varied picture content, a top–down template that guides recognition is less likely to be efficient, and moreover it would not rely on target diagnostic features. Since previous studies on natural scene categorization suggest that the effect of color information is critical when stimuli are extremely degraded (Castelhano & Henderson, 2008), and varies also as a function of stimulus status (target/distractor; Otsuka & Kawaguchi, 2009), future studies should evaluate the role of these variables on emotional processing.

In summary, the present work examined the influence of color on the affective modulation of the LPP during the perception of natural scenes. We found that the LPP affective modulation does not depend on picture color, even under challenging perceptual conditions such as when picture presentation is limited to a brief 24-ms flash. Essentially, color does not appear to act as a critical cue and/or uniquely allow for scene segmentation during emotional picture processing. Taken together, these results suggest that, despite demanding visual conditions, affective cues are recognized and activate the neural circuits mediating appetitive or defensive motivation, as indexed by the late positive potential.

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## Supporting Information

Additional supporting information may be found in the online version of this article:

**Figure S1:** Sensor cluster used to quantify the Late Positive Potential (400–800 ms).

**Figure S2:** Sensor cluster used to quantify the Early Posterior Negativity (150–300 ms).

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