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# Effects of social and affective content on exogenous attention as revealed by event-related potentials

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**ABSTRACT**

The social content of affective stimuli has been proposed as having an influence on cognitive processing and behaviour. This research was aimed, therefore, at studying whether automatic exogenous attention demanded by affective pictures was related to their social value. We hypothesised that affective social pictures would capture attention to a greater extent than non-social affective stimuli. For this purpose, we recorded event-related potentials in a sample of 24 participants engaged in a digit categorisation task. Distracters were affective pictures varying in social content, in addition to affective valence and arousal, which appeared in the background during the task. Our data revealed that pictures depicting high social content captured greater automatic attention than other pictures, as reflected by the greater amplitude and shorter latency of anterior P2, and anterior and posterior N2 components of the ERPs. In addition, social content also provoked greater allocation of processing resources as manifested by P3 amplitude, likely related to the high arousal they elicited. These results extend data from previous research by showing the relevance of the social value of the affective stimuli on automatic attentional processing.

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Successful behaviour depends on the ability of individuals to detect and appropriately process relevant stimuli from the environment. This capability to detect significant events relies on automatic, exogenous or bottom-up attention consisting in a reorientation of attention from the currently attended stimulus towards the new, significant stimulus (Carretié, 2014; Vuilleumier, 2005). This process is driven by the features of the new stimulus, such as relevance or salience (Brosch, Pourtois, Sander, & Vuilleumier, 2011; López-Martín, Albert, Fernández-Jaén, & Carretié, 2013) and may reflect a process of natural selective attention related to the appetitive and defensive motivational systems (Bradley, 2009; Schupp, Markus, Weike, & Hamm, 2003).

Previous research has demonstrated that affective stimuli attract or capture attention to a greater extent than non-affective stimuli (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004). This effect has usually been found by means of the presentation of an emotional distractor stimulus while subjects are performing a cognitive task. In these paradigms, emotional distractors capture greater exogenous attention than neutral distractors, as evidenced by a worse performance and longer reaction times (see Albert, López-Martín, & Carretié, 2010; Carretié, 2014; Carretié et al., 2004; Carretié, Ruíz-Padial, López-Marín, & Albert, 2011; Charash & McKay, 2002; Cisler, Olatunji, Lohr, & Williams, 2009). Previous studies have revealed the cortical activity supporting this mechanism, mainly through the recording of event-related potentials (ERPs).

The ERPs that have been previously related to exogenous attention are the group of N2 components and the anterior P2 (Bocquillon et al., 2014; Carretié, 2014; Carretié, Albert, et al., 2013). N2 set of

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components may be classified into anterior and posterior. The anterior N2 component is a negative peak appearing between 200 and 350 ms after stimulus onset at frontal scalp areas. This wave has been differentiated into two subcomponents (Folstein & Van Petten, 2008): a control-related N2, associated with conflict monitoring and cognitive control (e.g. Donkers & van Boxtel, 2004), and a novelty-related N2. The latter N2 subcomponent mainly responds to both novel visual stimulation and emotional stimulation (Bocquillon et al., 2014; Carretié et al., 2004; Chong et al., 2008; López-Martín et al., 2013). Previous studies using distraction and oddball paradigms have demonstrated enhanced anterior N2 for significant visual distractors and significant novel stimuli, such as affective pictures (e.g. Carretié et al., 2004; López-Martín et al., 2013). The posterior N2component, presenting parietal or parieto-occipital topography, has also been related to attention. Previous research has found two subcomponents of the posterior N2 (Luck, 2011): a contralateral component (N2pc), appearing in the electrode sites contrary to the side of a target stimulus, and a bilateral component (N2pb). This last component has been found to be related to classification of target stimuli in a visual search task (Luck & Hillyard, 1994). Hence, the N2 set constitutes good indices related to bottom-up, automatic attention driven by significant visual stimuli (López-Martín et al., 2013). Finally, anterior P2, a positive wave peaking at 180–200 ms and showing fronto-central topography, has been found to be enhanced by affective pictures, reflecting processes related to exogenous attention (e.g. Carretié et al., 2004; Carretié, Mercado, Tapia, & Hinojosa, 2001). For instance, Carretié et al. (2004) have shown that unpleasant affective pictures capture greater attention than other affective pictures, as reflected by anterior P2.

Human behaviour depends on the social environment, and emotions may be influenced by factors related to the social context (Adolphs, 2009). Thus, some authors have also highlighted that the social value of affective stimuli may have an influence on human behaviour (e.g. Britton, Taylor, Berridge, Mikels, & Liberzon, 2006). Previous research has shown that affective stimuli evoke different emotional responses depending on their social content. For example, several works have reported differences in autonomic reactions depending on the interaction between the social and affective content of the eliciting stimuli (Britton, Taylor, et al., 2006; Kosonogov, Sánchez-Navarro, Martínez-Selva, Torrente, & Carrillo-Verdejo, 2016). Convergent data from neuroimaging studies show that the neural regions involved in the processing of affective stimuli are also sensitive to their social value (e.g. Britton, Phan, et al., 2006; Norris, Chen, Zhu, Small, & Cacioppo, 2004). For example, an additive effect of the social value and the affective valence of the emotional stimuli has been found in the activity of the amygdala (Norris et al., 2004), as well as a joint activation in the dorsomedial prefrontal and medial parietal cortices when individuals view social interaction stimuli (Iacoboni et al., 2004). Sakaki, Niki, and Mather (2012) have also demonstrated that socially emotional pictures elicit greater activity in the medial prefrontal cortex, related to a more elaborative processing, than non-social emotional pictures. Moreover, the activity of the anterior paracingulate cortex has been related to understanding intentions of people involved in social interaction (Walter et al., 2004).

Few studies, however, have investigated the ERP correlates of the interaction between emotional and social factors, and these have revealed differences in early and late ERP components related to the social content of the stimuli. For example, Proverbio, Zani, and Adorni (2008) found larger parietal N2 amplitudes to emotional social scenes than to landscapes, whereas the amplitude of the bilateral anterior frontal N2 was larger in response to landscapes than to social scenes. In a subsequent study, Proverbio, Adorni, Zani, and Trestianu (2009) also found larger anterior N2 amplitudes to positive human scenes in contrast to both other positive stimuli that did not display humans and unpleasant pictures depicting humans, but only in women. Regarding later ERP components, Amaral, Simöes, and Castelo-Branco (2015) have recently reported an increase of the P3 amplitude at the right parietal region to attended complex social stimuli involving 3D animated human-like avatars.

A question that remains unsolved, however, is whether affective social stimuli would capture exogenous attention to a greater extent than other, non-social, affective stimuli. Previous studies have demonstrated that both emotional faces (a social stimulus) and emotional scenes (that may or not include social-related contents) used as distractors disrupt the subjects' performance in an on-going task (e.g. Carretié et al., 2011; Eastwood, Smilek, & Merikle, 2003). In addition, Carretié, Kessel, et al. (2013) have demonstrated that P2 amplitude is greater for unpleasant distractors – faces and scenes

– while N170 is more responsive to face distractors – independently of their affective valence. However, since the emotional scenes used in this work included both social (e.g. humans) and non-social contents (e.g. pictures depicting animals), no conclusion on the effect of the social content of the distractors on exogenous attention could be reached. The present work was aimed, therefore, at studying the attentional capture provoked by affective stimuli differing in social content. For this purpose, we employed a digit categorisation task on a background of affective pictures – used as distractors – that varied in affective valence and social content. While participants performed the task, we obtained measures related to the subjects' performance, as well as the cortical activity as revealed by ERPs.

We expected that the affective pictures, especially unpleasant pictures, would distract participants from the categorisation task and resulted in longer reaction times and/or worse accuracy than neutral distractors (e.g. Carretié et al., 2011; Carretié, Kessel, et al., 2013). In addition, we also expected that affective pictures with the greater social content would enhance attentional capture, resulting in less accuracy and/or longer response times than pictures with lower social content. Following previous research, we expected greater anterior and posterior N2 amplitudes and shorter latencies related to social distractors (Proverbio et al., 2008), especially for pleasant social distractors (e.g. Proverbio et al., 2009). Regarding anterior P2, greater amplitude and and shorter latency to unpleasant distractors, irrespective of their social content, were expected (Carretié, Kessel, et al., 2013). Lastly, we also expected that social distractors would provoke an increase of P3 amplitudes (Amaral et al., 2015).

## Methods

### *Participants*

A sample of 24 student volunteers (16 females) from the University of Murcia aged between 18 and 29 (*Mean* = 20.4, *SD* = 2.4) participated in the study. All subjects gave informed consent and received course credits for participation in the experiment. All procedures were conducted in accordance with the Declaration of Helsinki.

### *Stimuli and procedure*

We selected 113 pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and the EmoMadrid database (http://www.uam.es/CEACO/EmoMadrid.htm) according to their affective valence and arousal ratings. Following previous research (Kosonogov et al., 2016; Wardle & de Wit, 2012) pictures comprised 9 categories varying in emotional content (unpleasant, neutral and pleasant) and social content (0 people, 1 person, and 2 or more interacting people). Pictures did not differ in affective valence within each emotional content. In addition, the six pleasant and unpleasant categories did not differ in arousal level, as happened within the three neutral categories (all *ps* > .05).

Each category included 12 pictures. A different set of pictures of the "pleasant with one person" category was prepared for men and women, such that each contained seven pictures common to both male and female participants, while the other five pictures included opposite-sex erotica. Each picture was presented three times and, therefore, each subject passed through 324 trials (36 for each condition). In the centre of every picture appeared four random yellow Arabic digits (the entire row was 2.9° in height × 8.5° in width). Pictures were presented in a full screen mode on a 19-inch computer screen (33.2° in height × 44.2° in width) for 500 ms with an intertrial interval of 3500 ms. After each picture offset, a sound at 2000 ms indicated to participants that they could blink if necessary.

Participants were asked to press after picture onset as accurately and rapidly as possible one key if the second and the third digits were both even or both odd, and a different key if one of them was even, and the other was odd. In order to prevent possible influences of handedness, we asked half of the participants to use the left hand in the former case and the right hand in the latter, and half of the participants to do the opposite. We constructed three different presentation orders, and the participants were randomly assigned to one of them. For each order, pictures were pseudorandomly distributed along the 324 trials in such a way that three or more consecutive pictures of the same emotional or social content were not allowed.

The experiment was conducted in an isolated experimental chamber. The participants were accommodated in an armchair located 90 cm in front of a computer screen, and all sensors were then attached. The mean room temperature throughout the study was 22.0°C (*SD* = 2.8). After the EEG recording, all the sensors were removed and the participants were asked to view each picture again in a free viewing time setting and to rate the affective valence, arousal and social interaction using computerised scales. A 9-point scale was used for each dimension, with 9 representing a high rating (i.e. high pleasure, high arousal, high social interaction), and 1 representing a low rating (i.e. low pleasure, low arousal, no social interaction).

### *Data collection and reduction*

The electroencephalogram (EEG) activity was recorded form 31 active electrodes (Acticap, Brain Products, Germany) using a BrainAmp amplifier (Brain Products, Germany), according to the international 10–20 system. The electrode impedance was kept below 5 kΩ. The FCz electrode was used as online reference. Ocular movements were recorded through one electrode placed at the orbicular muscle below the right eye. The EEG signal was acquired using a bandpass filter of 0.05–40 Hz at a sampling rate of 500 Hz.

The EEG analysis was conducted off-line using the EEGLAB package (Delorme & Makeig, 2004). All channels were re-referenced to the common average. The recording was split into 1000 ms epochs, beginning 200 ms before stimulus onset. Eye-movement artefacts were corrected with least mean square regression analysis (Gómez-Herrero et al., 2006), and then trials with activity exceeding ±100 μV were rejected. All the trials with incorrect behavioural answers were also rejected. After the rejection of artefacts and the trials with incorrect behavioural answers the average admission of trials for each condition was: 82.64% for unpleasant without people, 78.47% for unpleasant with one person, 84.72% for unpleasant with two or more people, 84.72% for neutral without people, 86.10% for neutral with one person, 80.56% for neutral with two or more people, 81,25% for pleasant without people, 81.95% for pleasant with one person, and 81.95% for pleasant with two or more people. The number of valid trials did not differ depending on Emotional content, $F(2,46) = 0.72$, $p = .49$ or Social content, $F(2,46) = 0.47$, $p = .62$, and the interaction between Emotional content and Social content did not reach statistical significance, $F(4,92) = 1.23$, $p = .30$.

After a visual inspection of grand averages (Figure 1), and following previous findings on ERP responses (e.g. Carretié et al., 2011; Polich, 2007), we decided to find peaks for each participant and each condition for anterior sites (F3, Fz, F4, C3, Cz, and C4) in the time windows of 224–276 ms for anterior P2, and 276–360 ms for anterior N2. For posterior sites (P3, Pz, P4, O1, Oz, and O2) the time windows were 224–276 ms for posterior N2, and 276–450 ms for P3. For each ERP in the corresponding time windows we found the maximum amplitude peaks and their latencies of positive components and the minimum amplitude peaks and their latencies for negative components.

In the behavioural task, we measured reaction times and accuracy (the proportion of correct responses). All responses below 300 ms or above 2400 ms were discarded. For statistical analyses, reaction times were log10-transformed.

### *Data analysis*

Each dependent variable was analysed by a repeated measures ANOVA, 3 (Emotional content: unpleasant, neutral, and pleasant) × 3 (Social content: without people, one person, and two or more people). When appropriate, we applied the Greenhouse-Geisser adjustment to the degrees of freedom to correct any potential inflation of the reported probability values. For the main statistical tests partial eta-squared ($\eta_p^2$), a measure of the effect size, was obtained. Paired comparisons were performed with a Bonferroni correction (Keselman, 1998). For all the statistical tests the level of significance was .05, and only significant results were reported.

## Results

### *Behavioural data*

As shown in Table 1, though slower responses were found in trials with unpleasant pictures in the background than in neutral or pleasant trials, the statistical analyses only yielded a marginal main effect of Emotional content, $F(2,46) = 2.82$, $p = .070$, $\eta_p^2 = .11$. However, we found a significant main effect of the Social content on reaction time, $F(2,46) = 3.36$, $p = .043$, $\eta_p^2 = .13$, revealing slower responses in trials depicting one person in the background than in trials depicting two or more people ($p = .032$). Regarding accuracy, the statistical analyses did not reveal any significant effect on accuracy of Emotional content, Social content, or interaction between both (all $ps > .05$).

**Table 1.** Reaction times and accuracy (Means and SD) depending on the trial type.

| | 0 People | | 1 Person | | 2 or more people | | | |
|---|---|---|---|---|---|---|---|---|
| | *RT* | *Accuracy* | *RT* | *Accuracy* | *RT* | *Accuracy* | *RT* | *Accuracy* |
| Unpleasant | 1104.77 (201.28) | 0.880 (0.076) | 1141.66 (203.14) | 0.877 (0.068) | 1090.15 (182.42) | 0.876 (0.084) | **1112.19 (191.58)** | **0.878 (0.061)** |
| Neutral | 1094.65 (247.33) | 0.870 (0.090) | 1085.25 (190.53) | 0.888 (0.067) | 1093.36 (201.33) | 0.873 (0.052) | **1091.09 (207.62)** | **0.877 (0.060)** |
| Pleasant | 1096.61 (199.21) | 0.868 (0.066) | 1109.20 (216.35) | 0.873 (0.058) | 1090.39 (204.03) | 0.877 (0.076) | **1098.73 (201.91)** | **0.873 (0.058)** |
| | **1098.68 (208.60)** | **0.873 (0.067)** | **1112.04[a] (197.41)** | **0.879 (0.057)** | **1091.30[a] (192.62)** | **0.875 (0.060)** | | |

[a]The superscript means a significant difference between indicated values.
Note: The Last Column and the Last Row show the Means for each Emotional Content and Social Content, respectively.

## ERP components

### Anterior N2 component

We found a significant main effect of Social content on anterior N2 amplitude, $F(2,46) = 14.32$, $p = .001$, $\eta_p^2 = .38$. Pictures with one person and with two or more people provoked greater amplitudes than pictures without people, both $ps < .011$. In turn, pictures with two or more people provoked greater N2 amplitudes than pictures with one person, marginal effect, $p = .055$ (Figure 2). A significant Emotional content × Social content interaction on N2 amplitude, $F(2,46) = 5.95$, $p = .001$, $\eta_p^2 = .21$, was also found. Within unpleasant and neutral pictures, those depicting two or more people provoked greater N2 amplitudes than pictures without people or depicting one person, all $ps < .007$. Within pleasant pictures, those displaying one person or two or more people provoked greater amplitudes than pictures without people, all $ps < .011$.

We also found a significant main effect of Emotional content on N2 latency, $F(2,46) = 64.27$, $p = .004$, $\eta_p^2 = .21$. Unpleasant pictures (*Mean* = 332.83, *SD* = 15.72) provoked shorter latencies than neutral pictures (*Mean* = 339.69, *SD* = 16.14), $p = .013$, and a marginally shorter latency than pleasant pictures (*Mean* = 338.92, *SD* = 20.14), $p = .054$. A main effect of Social content on N2 latency was also significant, $F(2,46) = 3.98$, $p = .026$, $\eta_p^2 = .15$. Pictures with two or more people provoked shorter latencies than pictures without people, $p = .021$ (Figure 3).

### Posterior N2 component

A significant main effect of Social content on posterior N2 latency was found, $F(2,46) = 9.01$, $p = .001$, $\eta_p^2 = .28$. Pictures with one person and with two or more people provoked shorter posterior N2 latencies than pictures without people, both $ps < .020$ (see Figure 4). These effects were qualified by a significant Emotional content × Social content interaction on posterior N2 latency, $F(2,46) = 2.67$, $p = .037$, $\eta_p^2 = .10$. Neutral pictures with one person and with two or more people provoked shorter latencies than neutral pictures without people, both $ps < .027$. Pleasant pictures with two or more people also provoked shorter posterior N2 latencies than pleasant pictures without people, $p = .035$. We did not find any significant effect on posterior N2 amplitudes.

### Anterior P2 component

Analyses yielded a significant Emotional content × Social content interaction on anterior P2 amplitude,

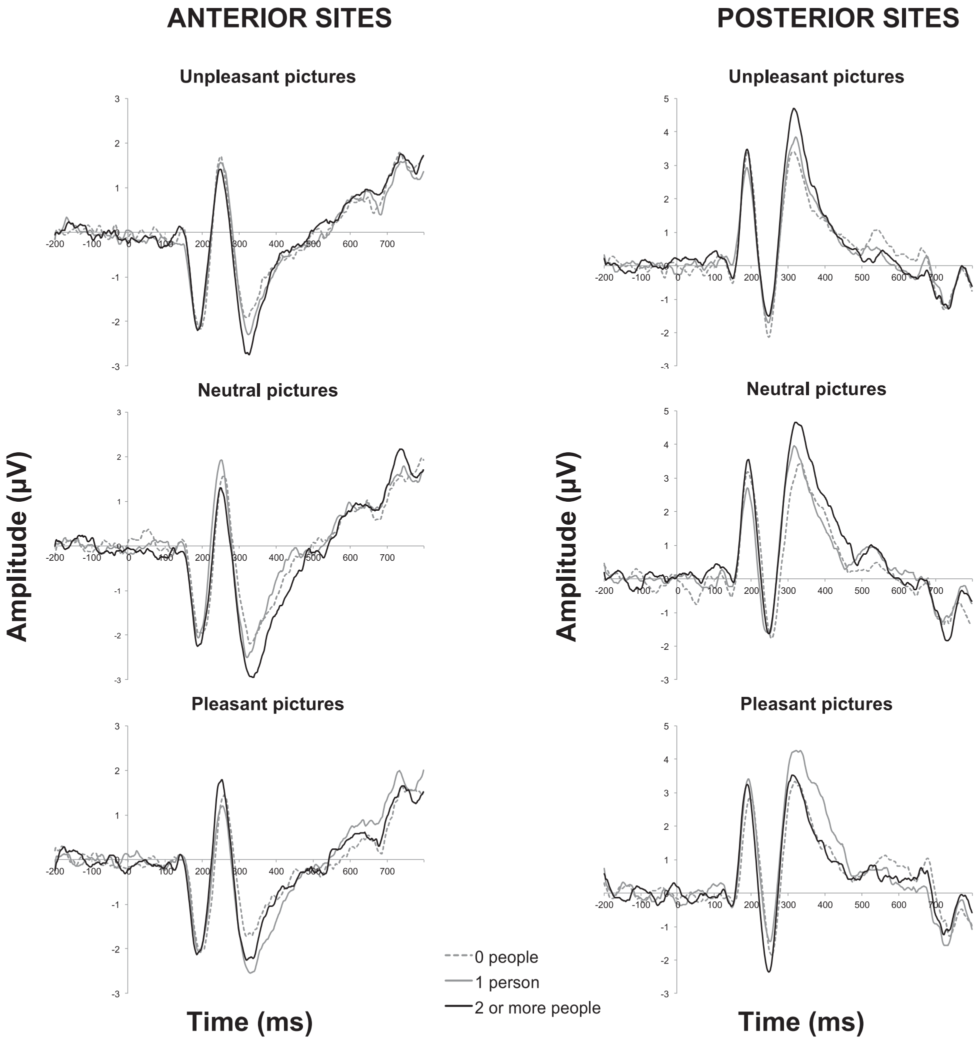


**Figure 1.** ERPs at anterior (F3, Fz, F4, C3, Cz, and C4; left column) and posterior (P3, Pz, P4, O1, Oz, and O2; right column) sites depending on background pictures.

$F(2,46) = 5.51$, $p = .001$, $\eta_p^2 = .19$. Neutral pictures with one person provoked greater amplitudes than neutral pictures with two people, $p = .002$. Pleasant pictures with two people provoked greater amplitudes than pleasant pictures with one person, $p = .024$.

We also found a main effect of Emotional content on P2 latency, $F(2,46) = 4.04$, $p = .024$, $\eta_p^2 = .15$. Unpleasant pictures (*Mean* = 252.00, *SD* = 9.03) provoked shorter latencies than pleasant pictures (*Mean* = 254.12, *SD* = 8.84), $p = .026$. A main effect of Social content on P2 latency was also significant, $F(2,46) = 17.90$, $p = .001$, $\eta_p^2 = .44$. Pictures with one person and with two people provoked shorter latencies than pictures without people, $p = .001$ (see Figure 5). This effect was qualified by a significant Emotional content × Social content interaction on P2 latency $F(2,46) = 5.65$ $p = .001$ $\eta_p^2 = .20$. Within neutral and pleasant pictures, those depicting one person or two or more people provoked shorter latencies than pictures without people (all *p*s < .011).

### *P3 component*

We found a significant main effect of Social content on P3 amplitude, $F(2,46) = 12.23$, $p = .001$, $\eta_p^2 = .35$ (see Figure 6). Pictures with one person (*Mean* = 5.43, *SD* = 1.77) and with two or more people (*Mean* = 5.66, *SD* = 1.73) evoked greater amplitudes than pictures without people (*Mean* = 4.81, *SD* = 1.72), both *p*s < .015.

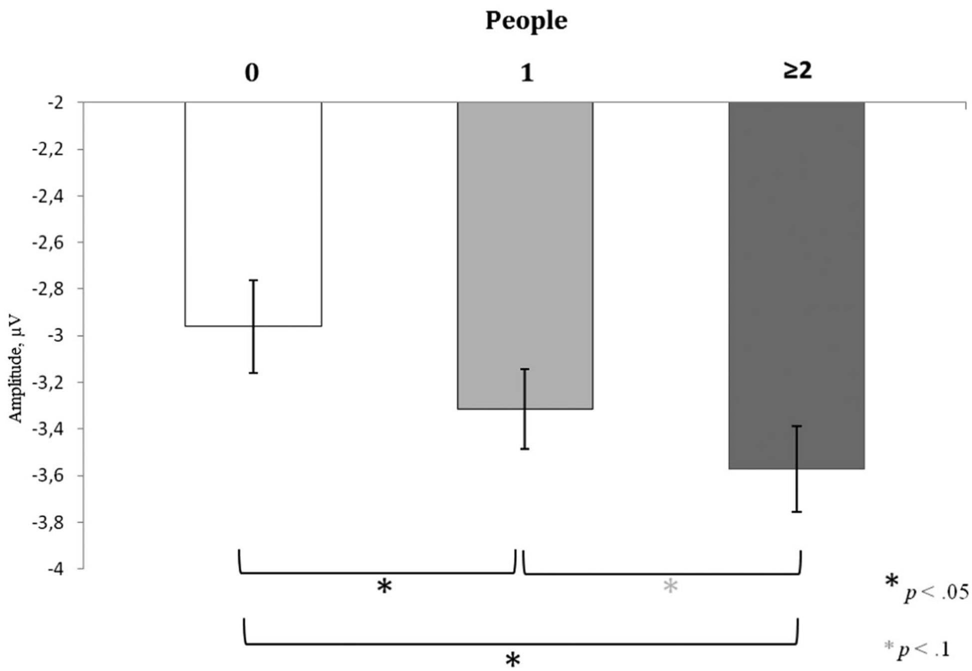


**Figure 2.** Anterior N2 amplitudes depending on social content of background pictures averaged across the three levels of emotional content (bars represent mean ± SEM).

This effect was qualified by a significant Emotional content × Social content interaction on P3 amplitude, $F(2,46) = 6.40$, $p = .002$, $\eta_p^2 = .22$. Within unpleasant and neutral pictures, pictures with two or more people provoked greater amplitudes than pictures depicting one person or without people, *all* $p$s < .049.

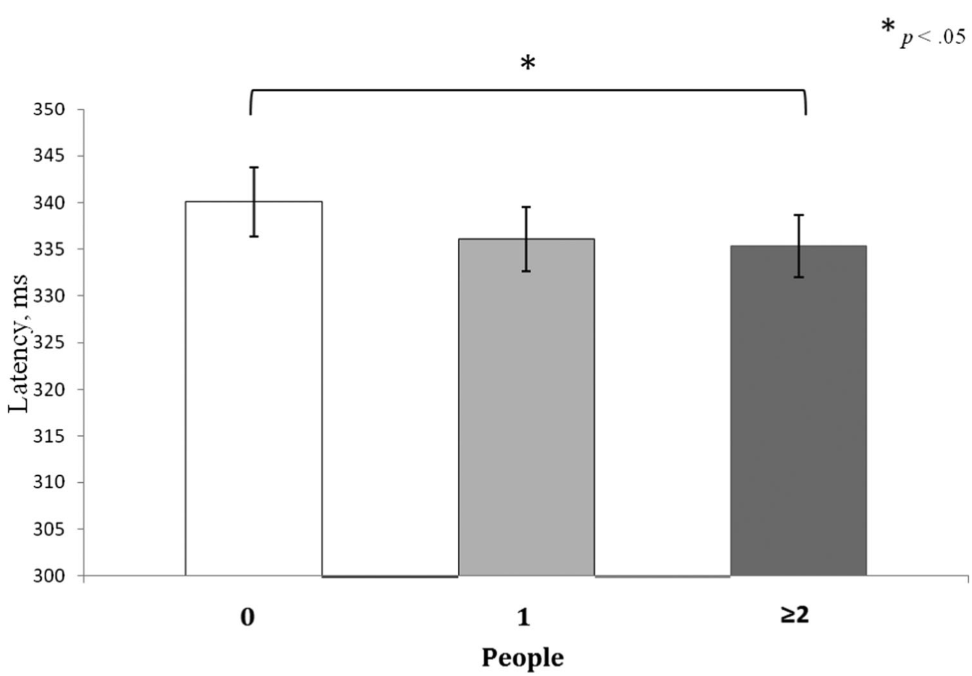


**Figure 3.** Anterior N2 latencies depending on social content of background pictures (bars represent mean ± SEM).

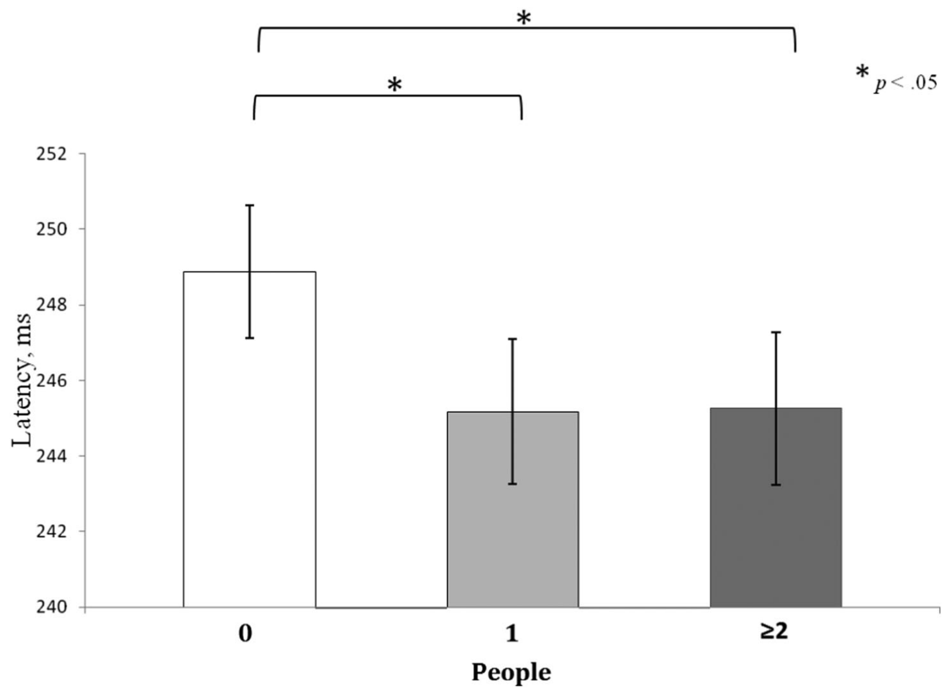


**Figure 4.** Posterior N2 latencies depending on social content of background pictures (bars represent mean ± SEM).

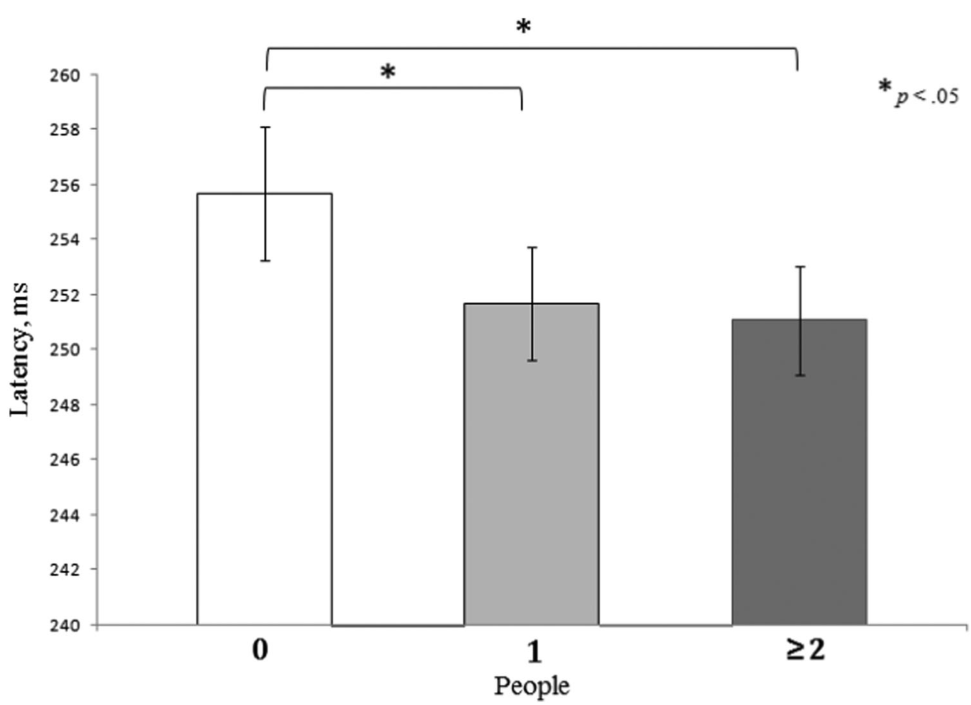


**Figure 5.** Anterior P2 latencies depending on social content of background pictures (bars represent mean ± SEM).

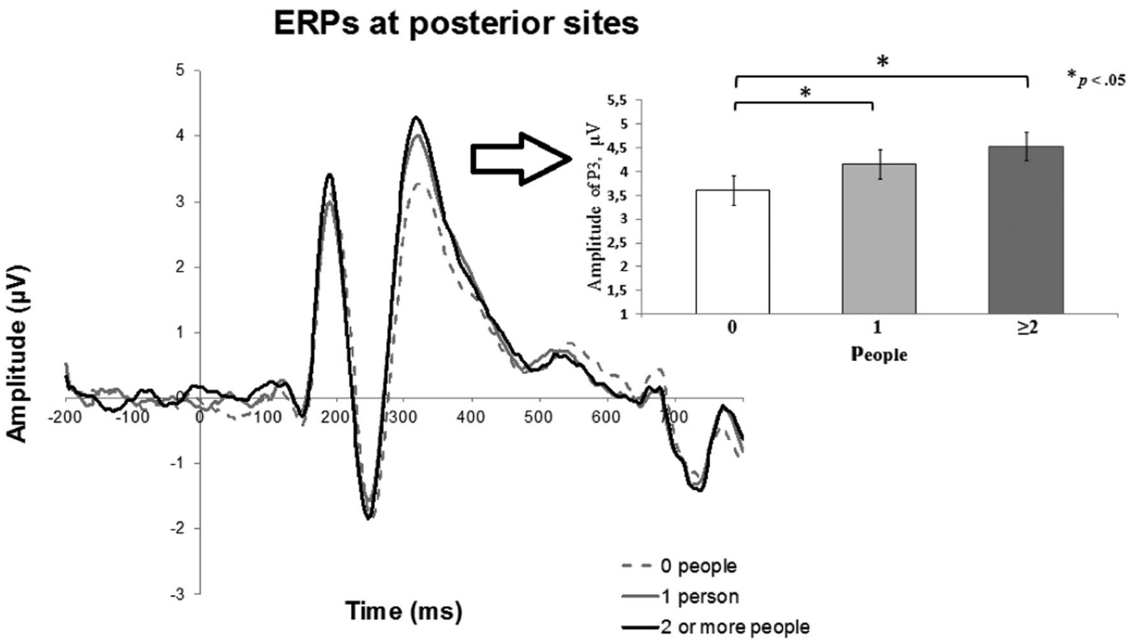


**Figure 6.** Grand average for ERPs recorded at posterior sites (electrodes P3, Pz, P4, O1, Oz, and O2) for each social content collapsed across emotional content (bars represent mean ± SEM).

Within pleasant pictures, pictures with one person provoked greater P3 amplitudes than pictures without people or with two or more people, both *p*s < .005.

## *Subjective evaluation*

### *Affective valence ratings*

A significant main effect of Emotional content was found, $F(2, 46) = 557.9$, $p < .001$, $\eta^2 = .96$, revealing that subjects rated the pleasant pictures with the highest affective valence, while the unpleasant pictures obtained the lowest ratings, (see Table 2). The Social content also yielded statistical significance, $F(2, 46) = 4.6$, $p = .015$, $\eta^2 = .17$, showing that participants also rated the pictures with one person with higher affective valence than the pictures with two or more people. A significant Emotional content × Social content interaction was also found, $F(4, 92) = 4.9$, $p = .001$, $\eta^2 = .18$. Unpleasant pictures without people were rated with higher affective valence than unpleasant pictures with two or more people ($p = .008$), and neutral pictures with one person were rated with higher affective valence than both neutral pictures without people ($p = .003$) and neutral pictures with two or more people ($p = .040$).

**Table 2.** Descriptive Statistics (Mean and SD) of the Subjective Evaluation of the Pictures.

| | Subjective ratings | | |
|---|---|---|---|
| | Affective valence (1–9) | Arousal (1–9) | Social interaction (1–9) |
| **Unpleasant** | **2.2 (0.5)** | **6.7 (1.3)** | **2.9 (0.9)** |
| 0 people | 2.4 (0.7) | 6.6 (1.4) | 1.4 (0.9) |
| 1 person | 2.3 (0.5) | 6.9 (1.3) | 1.9 (1.3) |
| 2 or more people | 2.0 (0.6) | 6.6 (1.4) | 5.6 (1.4) |
| **Neutral** | **5.2 (0.3)** | **2.9 (1.3)** | **2.7 (0.8)** |
| 0 people | 5.0 (0.3) | 2.1 (1.2) | 1.2 (0.4) |
| 1 person | 5.4 (0.7) | 3.5 (1.6) | 1.8 (1.1) |
| 2 or more people | 5.1 (0.3) | 3.1 (1.6) | 5.2 (1.6) |
| **Pleasant** | **7.3 (0.6)** | **6.2 (1.3)** | **3.7 (1.2)** |
| 0 people | 7.2 (0.6) | 5.7 (1.5) | 2.0 (1.7) |
| 1 person | 7.3 (0.7) | 6.4 (1.3) | 2.1 (1.5) |
| 2 or more people | 7.3 (0.7) | 6.5 (1.3) | 6.9 (1.5) |

### *Arousal ratings*

The analyses showed a significant main effect of Emotional content, $F(2, 46) = 111.6$, $p = .001$, $\eta^2 = .83$. Unpleasant and pleasant pictures were rated with higher arousal ratings than neutral pictures (see Table 2). A significant main effect of Social content was also found, $F(2, 46) = 38.0$, $p = .001$, $\eta^2 = .62$, with pictures depicting one person and pictures displaying two or more people receiving higher arousal ratings than pictures without people. In addition, we also found a significant Emotional content × Social content significant interaction, $F(4, 92) = 6.3$, $p = .001$,

$\eta^2 = .22$. For pleasant and neutral pictures, those depicting one person or two or more people were rated with higher arousal ratings than pictures without people.

### Social interaction ratings

A significant main effect of Emotional content, $F(2, 46) = 18.2$, $p = .001$, $\eta^2 = .44$, showed that pleasant pictures were rated with higher social interaction values than unpleasant and neutral pictures (see Table 2). In addition, the analyses also revealed a significant main effect of Social content, $F(2, 46) = 153.6$, $p = .001$, $\eta^2 = .87$. Pictures depicting two or more people were rated with the highest social interaction ratings, followed by pictures displaying one person and, in turn, by pictures without people.

## Discussion

The aim of this experiment was to study the effects of the social content of affective stimuli on attentional capture. For this purpose, we used a digit categorisation task and affective pictures varying in social content as distractors. Overall, our results revealed greater automatic exogenous attention through pictures depicting high social content, as reflected by anterior P2, and anterior and posterior N2 components of the ERPs. In addition, social content also provoked greater allocation of processing resources as manifested in P3, likely related to the high arousal they elicited.

According to the main hypothesis of this work, high social content captured attention to a greater extent than scenes with low social content, as reflected by both amplitude and latency of ERPs. Anterior N2 amplitude monotonically varied as a function of the social content, with pictures depicting the greatest social content evoking the largest N2 amplitudes. In addition, the latency of N2 at both anterior and posterior sites was shorter for pictures depicting persons in comparison to pictures without people. These data might relate to the salience of stimuli displaying people, and, therefore, to their capacity to attract attention (e.g. Proverbio et al., 2008). Previous research suggests that the ability to reorient attention from the current attended stimulus towards a new stimulus is an automatic process that depends on the significance or salience of the new stimulus (e.g. Carretié, 2014; Vuilleumier, 2005). As previously noted, this effect has been widely demonstrated, for example, in the case of affective stimuli (e.g. Carretié et al., 2004; López-Martín et al., 2013). In addition to the affective valence of the stimuli, our data on anterior N2 amplitude suggest that the automatic reorientation of attention might also be driven by the amount of social content displayed by the pictures. In the case of pleasant pictures, attentional capture was greater when one or more humans appeared in the scene, whereas neutral and unpleasant pictures captured greater attention only when several humans interacting appeared in the scene. This is in accordance with previous results showing larger N2 amplitude in women to positive human scenes in comparison to other pleasant pictures, as reported by Proverbio et al. (2009). These authors suggest that their results might be related to empathy, since the brain areas detected in the source localisation they carried out (BA31, BA38 and BA40) had been previously associated to empathy.

Previous studies have found that distractors related to human faces have the ability to capture attention to a greater extent than scenes, as shown by Carretié, Kessel, et al. (2013). However, because the set of stimuli they used as scenes included pictures displaying humans as well as pictures of animals, it is difficult to achieve a firm conclusion about the effect of the social content of the pictures on attentional capture. Our results replicated those obtained by Carretié, Kessel, et al. (2013), since we found that anterior P2 showed shorter latencies for unpleasant in comparison to pleasant pictures. In addition, our data extend their findings, revealing an effect of the social content on anterior P2, as well as on posterior N2, with distractors depicting humans (one person or two or more people) provoking shorter latencies. This effect on anterior P2, in addition, appeared mainly with pleasant and neutral pictures, but not with unpleasant ones. A possible explanation of the absence of differences in anterior P2 depending on the social content of the unpleasant stimuli might be related to a negativity bias reflecting the importance of displaying fast and strong responses to unpleasant stimuli of the environment independently of other attributes, such as their social content (Cacioppo & Berntson, 1994; Cacioppo & Gardner, 1999).

It has been proposed that anterior P2 and posterior N2 can constitute the positive and negative sides of a common generator source and be originated by the same neural structure, since both ERP components appeared in the same time window (Luck, 2011), Though previous research using source reconstruction has related the N2 component provoked by social scenes to the activity in several brain regions related to empathy (Proverbio et al., 2008, 2009), future research should further explore which neural regions related to the P2-N2 response are provoked by social distractors.

A later ERP component, P3 at parietal sites, showed an effect of the social content of the stimuli, with pictures depicting humans provoking larger amplitudes than pictures without people. These data are in accordance with previous research showing larger P3 responses to complex social stimuli in contrast to less complex ones (Amaral et al., 2015). The P3 response has been related to the motivational significance of the affective stimuli, and might reflect the allocation of processing resources to motivationally relevant stimuli (Ferrari, Bradley, Codispoti, & Lang, 2010; Hajcak, Weinberg, MacNamara, & Foti, 2012; Palomba, Angrilli, & Mini, 1997) as well as processes of memory update (for a review see Olofsson, Nordin, Sequeira, & Polich, 2008; Polich, 2007). Previous research has shown an effect of the arousal of affective pictures on P3 (e.g. Amrhein, Mühlberger, Pauli, & Wiedemann, 2004; Schupp et al., 2000), with maximum amplitudes appearing over parietal sites (Delplanque, Silvert, Hot, & Sequeira, 2005; Mini, Palomba, Angrilli, & Bravi, 1996). The subjective arousal data parallel the amplitude of the P3 amplitudes: both sets of data reveal that subjective arousal scores and P3 amplitudes increase together with the social content. This is in accordance with recent research showing larger skin conductance responses provoked by pictures depicting social content in comparison to pictures without social content (Kosonogov et al., 2016). Following this general relationship between P3 and arousal, our data on P3 amplitude revealed the salience of distractors depicting humans, and would reflect the reallocation of processing resources and memory update driven by highly motivational, social stimuli, since these were rated with higher arousal ratings than pictures that did not display humans.

Overall, the main effects of the emotional content influenced the latency of P2 and N2 at anterior sites: unpleasant pictures provoked shorter latencies than pleasant ones. The ERPs within the 200–300 ms latency range have been related to early discrimination of stimuli and response selection (Di Russo, Taddei, Apnile, & Spinelli, 2006) and they reflect attentional capture by emotional stimuli (Kanske, Plitschka, & Kotz, 2011). The shorter latency of these early components would be the result of the bottom-up, automatic attention driven by the salience of the unpleasant stimuli (Carretié, Kessel, et al., 2013; López-Martín et al., 2013). Accordingly, this result can reflect a process of "natural selective attention" related to the motivational systems of avoidance and approach (Schupp, Flaisch, Stockburger, & Junghöfer, 2006) that facilitates sensory encoding of affective stimuli (Amrhein et al., 2004).

Behaviourally, the type of emotional distractor exerted a marginal effect only on reaction times. According to previous studies showing greater attentional capture by affective stimuli (e.g. Carretié et al., 2004, 2011; Carretié, Kessel, et al., 2013), unpleasant pictures provoked slower reactions times than the other pictures. These results are not surprising, however, since a recent meta-analysis has demonstrated that this effect appears in only 66% of studies (Carretié, 2014). This study also reveals that neural indices are the most sensitive in detecting differential effects between emotional and neutral distractors, and a significant number of studies (30.91%) yield neural but not behavioural differences between emotional and neutral distractors. Similarly, no significant effect of the social content was found on behavioural data, with the exception that trials with pictures depicting two or more people provoked shorter reaction times than trials with pictures depicting one person – though none of them differed from the reaction times found in trials with pictures without people. Overall, and in agreement with Carretié (2014), the neural responses allowed a better discrimination than the behavioural indices in relation to the exogenous attention demanded by these pictures.

A limitation of this research might be related to the sample size, which probably leads to find only the largest effects. In this regard, a larger sample might result in larger and more stable estimates of the effects reported.

In conclusion, our data on anterior P2 and posterior N2 ERP components revealed greater exogenous attention provoked by high social content distractors. In addition, social contents also provoked greater allocation of processing resources, as revealed by P3 amplitude, which was likely related to the higher arousal elicited. These findings add to a growing literature on the processing of emotional and social stimuli that point to the relevance of social behaviour and the corresponding involvement of brain functioning.

## Statement

In this work, we have reported all the measures that were collected in all the experimental conditions, as well as the number of data per condition excluded from analyses.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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