

## RESEARCH ARTICLE

# Seeing emotions, reading emotions: Behavioral and ERPs evidence of the regulation of pictures and words

Alessandro Grecucci<sup>1</sup>\*, Simone Sulpizio<sup>2</sup>, Elisa Tommasello<sup>1</sup>, Francesco Vespignani<sup>1</sup>, Remo Job<sup>1</sup>

**1** Department of Psychology and Cognitive Sciences, University of Trento, Trento, Italy, **2** Faculty of Psychology, Vita-Salute San Raffaele University, Milano, Italy

\* These authors contributed equally to this work.

\* [alessandro.grecucci@unitn.it](mailto:alessandro.grecucci@unitn.it)



## Abstract

### Background

Whilst there has been extensive study of the mechanisms underlying the regulation for pictures, the ability and the mechanisms beyond the regulation of words remains to be clarified. Similarly, the effect of strategy when applying a regulatory process is still poorly explored. The present study seeks to elucidate these issues comparing the effect of regulation and of strategy to both neutral and emotional words and pictures.

### Methodology/Principal findings

Thirty young adults applied the strategy of distancing to the emotions elicited by unpleasant and neutral pictures and words while their subjective ratings and ERPs were recorded. At a behavioral level, participants successfully regulated the arousal and the valence of both pictures and words. At a neural level, unpleasant pictures produced an increase in the late positive potential modulated during the regulate condition. Unpleasant linguistic stimuli elicited a posterior negativity as compared to neutral stimuli, but no effect of regulation on ERP was detectable. More importantly, the effect of strategy independently of stimulus type, produced a significant larger Stimulus Preceding Negativity. Dipole reconstruction localized this effect in the middle frontal areas of the brain.

### Conclusions

As such, these new psychophysiological findings might help to understand how pictures and words can be regulated by distancing in daily life and clinical contexts, and the neural bases of the effect of strategy for which we suggest an integrative model.

## OPEN ACCESS

**Citation:** Grecucci A, Sulpizio S, Tommasello E, Vespignani F, Job R (2019) Seeing emotions, reading emotions: Behavioral and ERPs evidence of the regulation of pictures and words. PLoS ONE 14(5): e0209461. <https://doi.org/10.1371/journal.pone.0209461>

**Editor:** Christos Papadelis, Boston Children's Hospital / Harvard Medical School, UNITED STATES

**Received:** November 29, 2018

**Accepted:** May 21, 2019

**Published:** May 31, 2019

**Copyright:** © 2019 Grecucci et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Data Availability Statement:** Data have been uploaded on Open Science Forum DOI: [10.17605/OSF.IO/H6J9E](https://doi.org/10.17605/OSF.IO/H6J9E).

**Funding:** The authors received no external funding for this study.

**Competing interests:** The authors have declared that no competing interests exist.

## Introduction

Visual, auditory and other sensory modalities have specific neural circuitry to process the emotional meaning carried by incoming stimuli. Hardwired in specific brain mechanisms such a circuitry evolved to respond to relevant situations with efficient responses. However, for successful adaptation to an ever-changing environment, sometimes in-coming stimuli need to be regulated before being channeled into action [1,2]. This may be necessary in order not to be overwhelmed or distracted by the emotional impact of the situations. Although in the last twenty years we have come to know the basic neural structures involved in emotional perception and regulation by means of the extensive usage of neuroimaging techniques such as functional Magnetic Resonance Imaging (fMRI) (see [3], for a review), the temporal dynamics associated with the regulation of emotional pictorial and linguistic stimuli are not completely understood. In the present paper, we start to overcome this limitation by unveiling electrophysiological activity of people regulating their response to emotional pictures and words. Electroencephalography is possibly the best way to capture the temporal dynamics of complex psychological events that unfold over time since it allows to identify, with a precision of milliseconds, close but subsequent events and to track their temporal development. An advancement in the actual emotion regulation field would be to better understand the regulation of emotion elicited by words, and to compare such findings with those elicited by pictures. In daily life, we usually express emotions by means of words, and we react with emotions to other people words. A case in point, is what happens during a psychotherapy session where the clinician uses language to elicit and regulate patients' emotions, and to understand the emotional states of patients by listening to their words [1,2,4]. Freud defined psychotherapy "a cure through words" [5]: a cure to help patients express and possibly regulate linguistic contents. Despite its relevance in daily life and in clinical situations, the experimental investigation of the processes involved in regulating emotions conveyed by words are just at the beginning. Indeed, most of the previous experiments were focused on the regulation of emotional pictures rather than emotional words. To our knowledge there are only few experiments testing the effect of emotion regulation on words. In one experiment [6], participants were asked to regulate emotions to unpleasant pictures and then were asked to judge whether a word was negative or neutral. Event-related potentials (ERPs) revealed a reduction in N400 and an increase in P300 amplitude to words presented after enhancing and suppressing unpleasant emotions, respectively. However, in this experiment the modulation of words followed a previous modulation of pictures, making it hard to disentangle the regulation of pictures from the regulation of words. Moreover, participants performed a decision task while reading the words, and this may have distracted participants from the regulation task. More recently, Speed et al., [7] used an Autobiographical emotion regulation task (AERT) to study the possibility of regulating the emotions elicited by linguistically cued autobiographical memories. However, in this experiment words were used only to cue autobiographical memories, and not as a target of regulation. Thus, the first aim of this paper is to provide clear evidence on the regulation of emotional linguistic stimuli. In order to allow for possible comparisons with well-established findings of effects of regulation, we developed an integrated paradigm in which, in separate blocks, participants regulate emotional pictures or words. In each block neutral stimuli were also present.

The majority of previous studies used reappraisal (in the form of reinterpretation) and distraction, two largely studied regulatory strategies [8,9,10]. However, reinterpretation and distraction are just two examples of a vast set of regulation strategies people use. Reappraisal typically involves an effort to generate an alternative interpretation of the incoming stimulus [11]. Distraction-based strategies, as the one used by Schönfelder and colleagues [12], required

subjects to apply mental operations (performing arithmetic calculations while observing the emotional stimuli). In the present study we used distancing [13,14]. This strategy does not require participants to perform inferential (reappraisal) or mathematical operations (distraction). It simply implies to put oneself in a detached perspective as if the incoming stimulus has nothing or little to do with oneself. Thus, departing from previous studies, the second aim of the present study is to test the ability to regulate emotional words and pictures by using distancing.

Beside the type of strategy used, another challenge in the current debate concerning emotion regulation is the possibility to disentangle the *effect of strategy* from the *effect of regulation*. The effect of strategy (ES) concerns the implementation of the strategy, whereas the effect of regulation (ER) is related to the regulation of emotions to which the strategy was applied. In an fMRI study, Grecucci et al [15,16] showed that different brain networks were linked to ES (how the brain responds when the subjects applied the strategy) and to ER (how specific brain regions are regulated by the strategy). Specifically, strong activation of dorsolateral prefrontal cortex was associated with ES while reduced activation of insula, among other structures, was associated with ER. These results were based on statistical contrasts inside the same temporal window, thus making it hard to disentangle the effects of the two processes. More related to ERPs, authors found in the reappraisal condition a reduced Late Positive Potential (LPP) as possible ER. LPP is a positive slow component with a posterior distribution, which is sensitive to the emotional content of the stimuli and is larger for emotional than neutral stimuli [17]. A reduction of LPP was also reported by Moser et al. [18], using the strategy of suppression, and by Foti and Hajcak [19], who investigated the modulation of neutral vs negative effect of descriptions before the image was presented. Schönfelder and colleagues [12] showed a reduction in emotional activation when participants used a distraction strategy but also, to a lesser extent, when they used a reappraisal-based strategy. Paul et al. [20] showed a reduction of LPP when participants used distraction and reappraisal-based strategies. Gan and colleagues [21] replicated the effect of reduction of emotion enhanced LPP when participants applied reappraisal and observed an increase of N2 for the suppression strategy, possibly related to the control of facial expression. More recently, Qi et al. [22] used detached reappraisal (similar to what we indicate with the term distancing) to regulate unpleasant pictures and reported a modulation of LPP. However, these experiments mainly focused on the ER. Studies that specifically focused on the ES found an increased Stimulus Preceding Negativity (SPN) [23–25,26] in the pre-implementation period, for reappraisal but not for distraction [24], and interpreted it as enhanced recruitment of attentional resources. In the present experiment, we aimed at temporally separating ES from ER by detecting the associated ERPs in their respective temporal windows. In order to do so, we analyzed two well defined and distant time windows, to detect separate cortical responses of the ER from the ES. This can lead to the discovery of specific neural markers when participants apply the strategy of distancing (ES) beside effects of emotion regulation (ER). In sum, we aim at testing three main hypotheses: 1) we hypothesize that emotional words can be regulated in both the arousal (e.g. the strength of the perceived emotion), and valence (the perceived pleasantness of the stimulus) dimensions in a similar fashion to what has been previously shown for pictures; 2) we hypothesize that distancing is able to regulate both emotional words and pictures; last but not least 3) we hypothesize that separate and different ERP components can be associated with the effect of regulation (in the time window of the stimulus to regulate) from the effect of strategy (in the time window of the presentation of the strategy to apply before the stimulus presentation). The effect of regulation should be manifested in well-known components such as the modulation of LPP. By contrast, we hypothesize a different component at anterior sites for the effect of regulation, based on previous EEG [23–25], and fMRI studies [15,16].

## Method

### Participants

Thirty-one adults participated in the experiment. The data of one participant was discarded because of the very high number of artifacts in the EEG data. The final sample was of 30 participants (23 female, 7 males; mean age of participants: 22.37, SD: 3.23; mean years of education: 15.93, SD: 2.63). All participants were right-handed, Italian native speakers; they had normal or corrected-to-normal vision, and reported to be neurologically healthy. Participants gave written informed consent to their participation after they were informed about the nature of the study. Participants received a small financial reward to take part in the study. The study was approved by the ethical Committee of the University of Trento following the declaration of Helsinki guidelines.

### Materials and design

**Behavioral paradigm.** The experiment comprised both picture and word as stimuli which participants were trained to attend (baseline condition), or to regulate (experimental condition) upon. Pictures and words stimuli were taken from the International Affective Picture System (IAPS, [27]), and from the Affective Norms for English Words (ANEW for Italian, [28]), respectively. These stimuli could be neutral and negative according to their valence. Eighty stimuli per each category were selected for a total of 160 pictures and 160 words. The negative pictures had low valence ( $M = 2.56$ ,  $SD = 0.64$ ) and medium-high arousal ( $M = 6.09$ ,  $SD = 0.51$ ). The neutral pictures had medium valence ( $M = 5.29$ ,  $SD = 0.57$ ) and low arousal ( $M = 3.09$ ,  $SD = 0.68$ ). Both neutral and negative pictures were divided into two subsamples and associated with the two experimental conditions (attend vs distancing). Importantly, they did not statistically differ (valence of negative subsample 1 vs negative subsample 2,  $t(78) = 0.68$ ,  $p = .946$ ; arousal of negative subsample 1 vs negative subsample 2,  $t(78) = -0.257$ ,  $p = .798$ ; valence of neutral subsample 1 vs neutral subsample 2,  $t(78) = -0.787$ ,  $p = .434$ ; arousal of neutral subsample 1 vs neutral subsample 2,  $t(78) = 0.277$ ,  $p = .783$ ).

The negative words had low valence ( $M = 2.42$ ,  $SD = 0.49$ ) and medium-high arousal ( $M = 6.45$ ,  $SD = 0.24$ ). The neutral words had medium valence ( $M = 6.07$ ,  $SD = 0.78$ ) and low arousal ( $M = 4.15$ ,  $SD = 0.60$ ). Negative and neutral words were matched on the following psycholinguistic variables: Written frequency, length in letter, and orthographic neighborhood size ( $t < 1.68$ ,  $p > .09$ ). Stimuli were divided into two subsets (one per experimental condition). Every participant was exposed to one of the two subsets associated with one of the two experimental conditions. Both neutral and negative words were divided into two subsamples and associated with the two experimental conditions (attend vs distancing). They did not statistically differ (valence of negative subsample 1 vs negative subsample 2,  $t(78) = -0.296$ ,  $p = .768$ ; arousal of negative subsample 1 vs negative subsample 2,  $t(78) = -0.823$ ,  $p = .413$ ; valence of neutral subsample 1 vs neutral subsample 2,  $t(78) = 0.505$ ,  $p = .615$ ; arousal of neutral subsample 1 vs neutral subsample 2,  $t(78) = 0.223$ ,  $p = .824$ ). Each linguistic and pictorial stimulus was presented once, the order of presentation of each stimulus inside each block was completely randomized, and the two blocks (one for picture and one for words) was randomized across subjects. All participants received both subsets of stimuli. The two subsets were associated one with the regulate, and the other with the attend condition. Half of the participants observed the first subset in the regulate condition, and the second in the attend condition; the other half of participants received the second subset in the regulate condition, and the first in the attend condition. After the fixation point (1000 ms), instructions on the regulatory strategies were given (attend, or distancing, for 3000 ms). This was the time window to extract

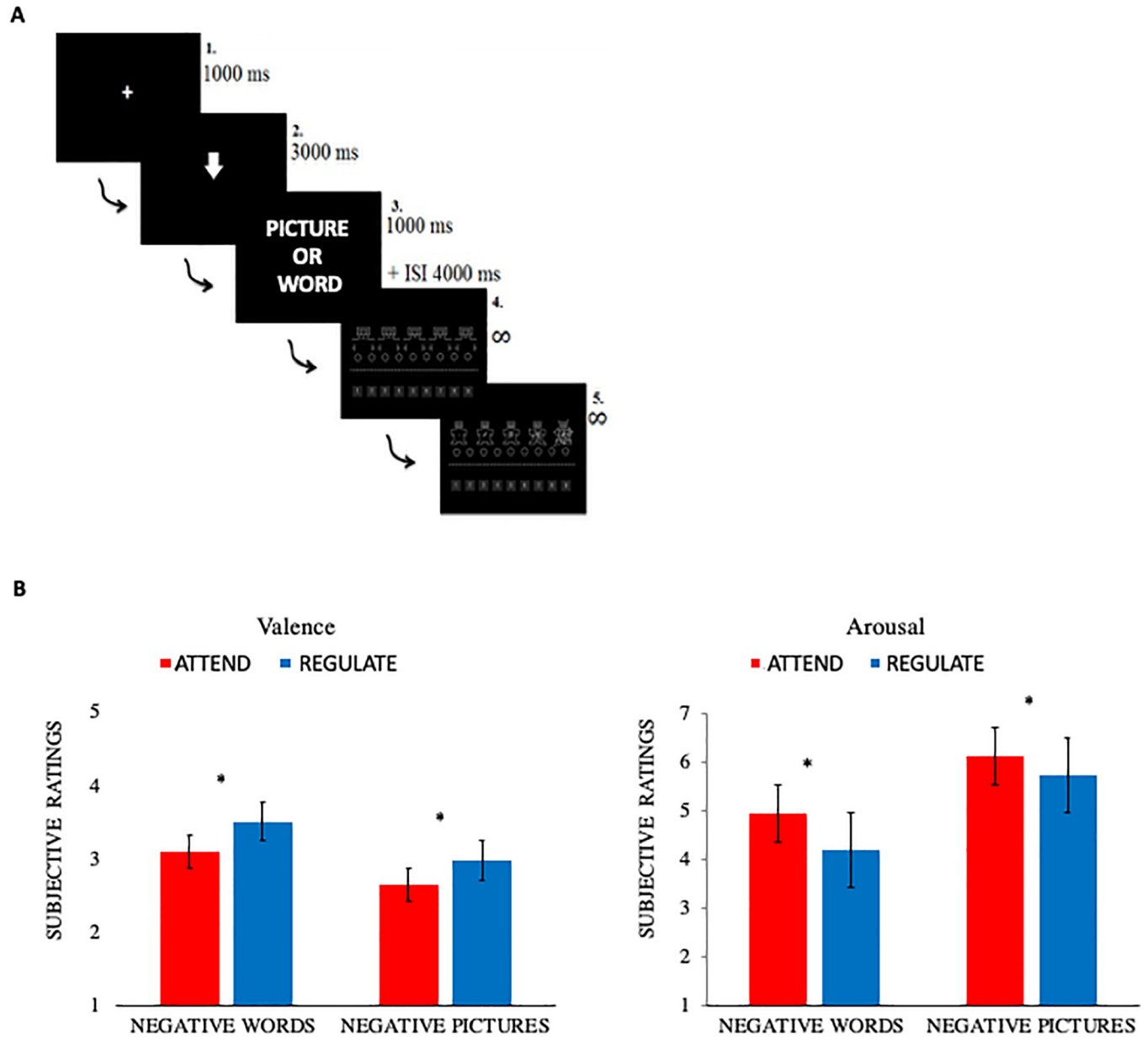
the signal relative to the Effect of Strategy. To avoid, linguistic confounding we used a circle to indicate the attend condition, and a downward arrow to indicate distancing. Then the stimulus (picture or word separated in blocks) was presented for 1000 ms. After the stimulus, a black screen appeared for 4000 ms. In sum, 5000 ms were given for the perception and regulation of emotions elicited by the stimuli. Then participants rated their emotions according to the valence and arousal dimensions on two separate scales, by using the standard Self-Assessment Manikin (SAM) procedure on a 1 to 9-points Likert scale [29]. The SAM-valence scale represented how negatively the stimuli were perceived, where 1 is very negative and 9 very positive. The SAM-arousal scale represented the strength of the perceived emotion elicited by the stimuli, where 1 indicated low arousal, and 9 high arousal. After each stimulus, participants had to indicate their preference by pressing a number on the keyboard. An interstimulus interval of 3000 ms was then presented before next trial. See Fig 1A.

Before the experiment, a two page written protocol describing how to apply the emotion regulation strategy of distancing and how to simply attend to the stimuli, was given. In brief, in this protocol, participants were first told that the degree of involvement to a given situation affects the type and strength of emotions they feel. A picture was then presented depicting a bloody fight between police and terrorists, and they were told that if they feel themselves affected by this situation they probably will feel scared and worried, whereas if they think that that situation is far from their lives and not connected at all with them, they will feel quite neutral in relation to that event. After this, subjects were told how to apply this strategy to the context of the experiment. They were asked to put themselves in a detached perspective as if that event was far from their lives and not connected at all with them. Two examples were given. A negative picture, and a negative word were presented accompanied by the explanation on how to apply the strategy. In the attend condition, they were asked to respond naturally, without using any specific strategy (see [14] for a complete description of the protocol). Before beginning the first block of the experiment, we verified that participants understood the respective emotion regulation instructions by asking each to verbalize what they would do when confronted with different stimuli. A practice session proceeded every block.

**EEG procedure.** EEG was recorded from 60 scalp electrodes (Fp1, Fpz, Fp2, AF7, AF3, AF4, AF8, F9, F7, F5, F3, F1, Fz, F2, F4, F6, F8, F10, FT7, FC5, FC3, FC1, FCz, FC2, FC4, FC6, FT8, T7, C5, C3, C1, Cz, C2, C4, C6, T8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, TP10, P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, PO3, POz, PO4, PO4, PO8, O1, Oz, O2) mounted on an elastic cap, positioned according to the international standard position (10–20 system). Additional external electrodes were placed 2 below the eyes (Ve1, Ve2) and 2 lateral to the external canthi (He1, H2). Electrodes were referenced to Cz; the ground was placed anteriorly to AFz. Impedance was kept below 10 k $\Omega$ . Data were acquired at the sampling rate of 1000 Hz with a low-pass filter with 100 Hz cutoff frequency and 10s time constant.

Offline analysis was performed with Brain Vision Analyzer II software (Brain Products GmbH, Munich, Germany). Data were down sampled at 250 Hz and re-referenced to an average reference; the signal of Cz was reconstructed. Data were filtered with a low pass filter (40 Hz cutoff, 12 dB/oct) and a high-pass filter (0.05 Hz cutoff, 12 dB/oct sec). Two virtual EOG channels were off-line computed as the difference between the average of Fp1 and Fp2 and the average of Ve1 and Ve2 (VEOG), and as the difference between He1 and He2 (HEOG). The signal was corrected for eye blinks and ocular movements by means of Independent Component Analysis. Ocular electrodes were then excluded from subsequent analyses as well as other four electrodes (AF7, AF8, F7, F8) due to their very high level of noise in all participants.

The EEG signal was segmented in two ways in order to have strategy segmented epochs, lasting from 500 ms before until 3000 ms after strategy onset, and target segmented epochs,



**Fig 1. Timeline of events (A) and behavioral results (B).** Participants showed an effect of regulation for both words and pictures when applying the regulation strategy. Distancing reduced arousal (strength of perceived emotions), and increased valence (perceived as less negative) for negative pictures and words. Error bars indicate the standard error of the mean, asterisks significant differences. Y-axes were adapted to the size of the effect and do not report the whole 1 to 9-Likert scale.

<https://doi.org/10.1371/journal.pone.0209461.g001>

lasting from 500 ms before until 2000 ms after target onset. In both cases, the segmented epochs in which the voltage exceeded ( $-100\mu\text{V}$ ,  $100\mu\text{V}$ ) in any of the channels were rejected as affected by artifacts (overall, 70% of strategy trials and 77% of target trials were kept for analyses). For the strategy epochs, single subject waveforms for each condition were averaged in reference to the 400 ms prestimulus baseline whereas for the target epochs they were averaged in reference to 300 ms prestimulus baseline.



## Results

### Behavioral results

We first computed a general within subjects ANOVA on SAM ratings with all factors: Index (Valence vs Arousal), Regulation (Distancing vs Attend), Stimulus (Pictures vs Words) and Emotional content (Negative vs Neutral). Analysis returned a significant main effect of Regulation ( $F(1,29) = 20.040, p = 0.000$ ), Stimulus ( $F(1,29) = 6.817, p = 0.014$ ), and Emotional content ( $F(1,29) = 4.996, p = 0.033$ ), as well as a significant interaction between Index and Regulation ( $F(1,29) = 16.307, p = 0.000$ ); Index and Emotional content ( $F(1,29) = 303.650, p = 0.000$ ); Stimulus and Emotional content ( $F(1,29) = 42.394, p = 0.000$ ); Index, Regulation and Emotional content ( $F(1,29) = 20.464, p = 0.000$ ); Index, Stimulus and Type ( $F(1,29) = 41.835, p = 0.000$ ).

Next, we computed two separate within subjects ANOVAs one for each Stimulus type. For Pictures, analysis returned a significant effect of Regulation ( $F(1,29) = 7.681, p = 0.009$ ), Emotional content ( $F(1,29) = 18.092, p = 0.000$ ), as well as the interaction between Index and Strategy ( $F(1,29) = 7.845, p = 0.009$ ), Index and Emotional content ( $F(1,29) = 235.208, p = 0.000$ ), and the three-way interaction Index, Regulation and Emotional content ( $F(1,29) = 12.350, p = 0.001$ ). To explore the triple interaction, we computed Bonferroni corrected post hoc on the arousal and the valence of each category by adjusting the p-value. For Arousal, there was a significant difference between distancing and attend for negative pictures ( $p = 0.002$ ), but not for neutral pictures ( $p = 0.157$ ). Distancing reduced arousal (strength of perceived emotions) when applied to negative pictures. Neutral and negative pictures differed from each other in both conditions ( $p = 0.000$ ). See Table 1 and Fig 1B. For Valence, there was a significant difference between distancing and attend for both negative pictures ( $p = 0.006$ ), and neutral pictures ( $p = 0.001$ ). Distancing increased valence (perceived as less negative). Neutral and negative pictures differed from each other in both conditions ( $p = 0.000$ ). See Table 1 and Fig 1B. We also computed the effect of Regulation (collapsing for other relevant conditions). For both Arousal and Valence, distancing had a significant effect on SAM ratings when compared to attend (respectively,  $p = 0.016; p = 0.000$ ). In other words, distancing reduced the arousal and increased the valence of stimuli.

For Words, analyses returned a significant effect of Regulation ( $F(1,29) = 16.738, p = 0.000$ ), an interaction between Index and Regulation ( $F(1,29) = 17.606, p = 0.000$ ), Index and Emotional content ( $F(1,29) = 262.059, p = 0.000$ ), and the triple interaction Index, Regulation and Emotional content ( $F(1,29) = 20.248, p = 0.000$ ). To explore the triple interaction, we computed Bonferroni corrected post hoc (threshold  $p < 0.02$ ) on the arousal and the valence of

Table 1. SAM mean ratings and standard deviations for pictures and words.

	Pictures			
	Look		Distancing	
	Neutral	Negative	Neutral	Negative
Valence	5.29 (0.31)	2.64 (0.70)	5.11 (0.33)	2.97 (0.87)
Arousal	2.62 (1.51)	6.13 (1.45)	2.54 (1.58)	5.70 (1.38)
	Words			
	Attend		Distancing	
	Neutral	Negative	Neutral	Negative
Valence	5.30 (0.44)	3.08 (0.55)	5.11 (0.30)	3.43 (0.74)
Arousal	2.95 (1.56)	5.06 (1.49)	2.77 (1.50)	4.33 (1.64)

<https://doi.org/10.1371/journal.pone.0209461.t001>

each category. For Arousal, there was a significant difference between distancing and attend for negative words ( $p = 0.000$ ), but not for neutral words ( $p = 0.044$ ). Distancing decreased the arousal of negative words. Neutral and negative words differed from each other in both conditions ( $p = 0.000$ ). See [Table 1](#) and [Fig 1B](#). For Valence, there was a significant difference between distancing and attend for negative words ( $p = 0.002$ ), but not for neutral words ( $p = 0.014$ ). In other words, distancing increased the valence of negative words. Neutral and negative words differed from each other in both conditions ( $p = 0.000$ ). See [Table 1](#) and [Fig 1B](#). We also computed the effect of Regulation (collapsing for other relevant conditions). For both Arousal and Valence, distancing had a significant effect on SAM ratings when compared to attend (respectively,  $p = 0.000$ ;  $p = 0.001$ ). In other words, distancing reduced the arousal and increased the valence of stimuli.

## ERPs results

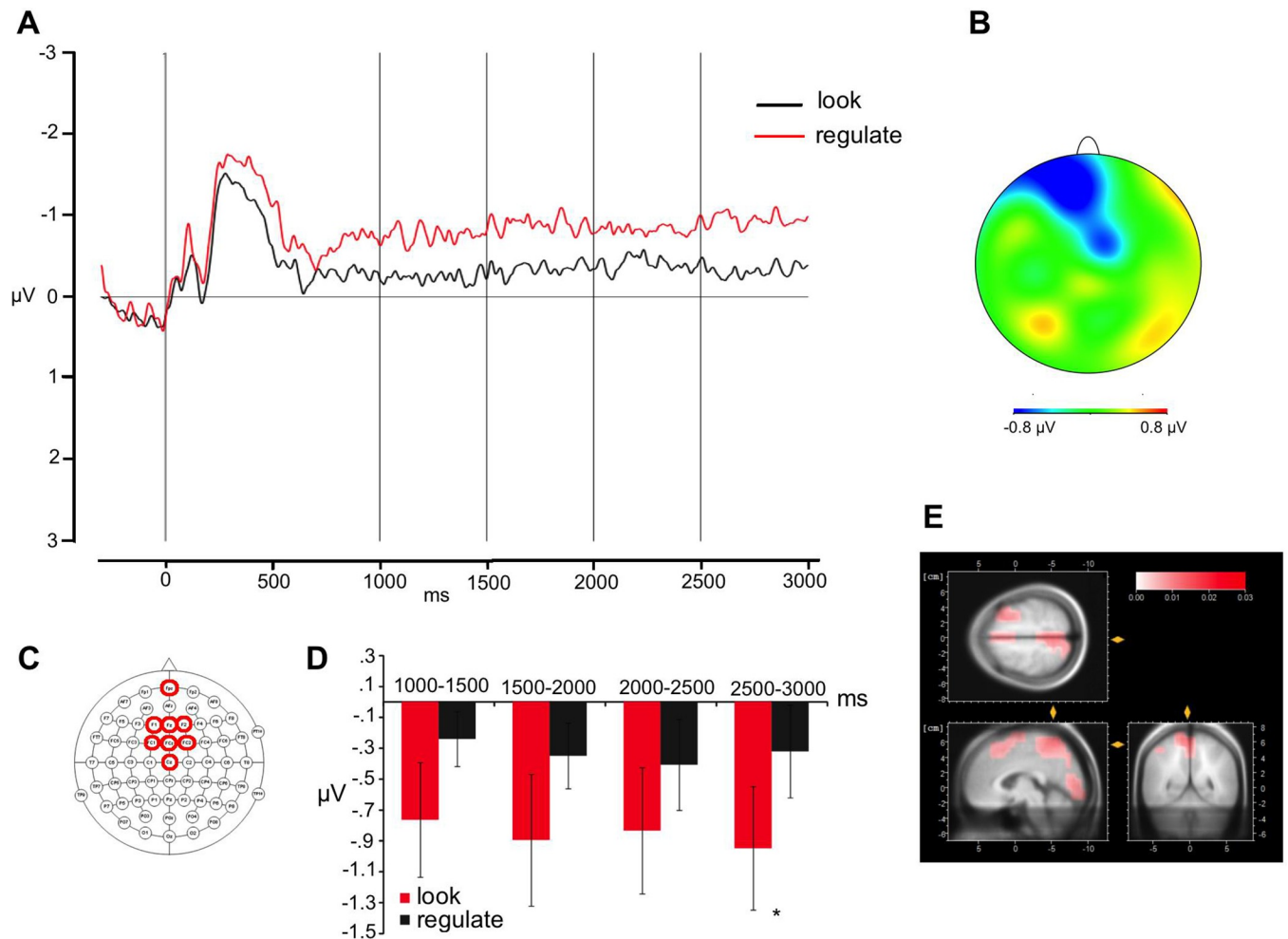
ERPs results were separated into Effects of Strategy (distancing versus attend conditions during the time window of the presentation of the strategy), and Effects of Regulation (distancing vs attend when stimuli are presented).

**Effect of strategy.** Visual inspection of the targets grand-averages shows that, compared to the attend condition, the regulate condition elicited a broadly distributed centro-frontal negativity (see [Fig 2](#)). The difference appears for both picture and word targets, although it seems more pronounced for pictures. For its polarity and distribution, the effect may be classified as a Stimulus Preceding Negativity (SPN), a slow and long-lasting component usually occurring in anticipation of a variety of cognitive, attentive and emotional task-relevant stimuli [30]. To investigate whether the difference between the attend and distancing condition was significant, analyses were run in four consecutive time windows of 500 ms each, starting 500 ms after strategy presentation and ending at the target presentation. Following the visual inspection of grand-averages, a fronto-central pool of electrodes was created by averaging the channels: Fpz, F1, F2, Fz, FC1, FC2, FCz, Cz, CPz. A 2 x 2 ANOVA with Strategy (attend vs distancing) and Target (pictures vs words) as within-participants factor was run.

In the first three time-windows, no effect reached significance (1000-1500ms time window: all  $F_s < 2.6$ ,  $p_s > 0.1$ ; 1500-2000ms time window: all  $F_s < 3.1$ ,  $p_s > 0.09$ ; 2000-2500 ms time window: all  $F_s < 2.9$ ,  $p_s > 0.1$ ). In the fourth time-window, i.e., between 2500 and 3000 ms after stimulus onset, there was a main effect of Strategy ( $F(1, 29) = 4.49$ ,  $p = 0.04$ ), with a larger negativity for the regulate (average voltage in the time window =  $-0.95\mu V$ ) than the attend condition (average voltage in the time window:  $-0.32\mu V$ ); no further effect reached significance (Target:  $F < 1$ ; Strategy x Target:  $F < 1$ ). See [Fig 2A, 2B, 2C and 2D](#).

In order to visualize the neural generators of these scalp effects, and make eventual comparison with previous fMRI experiments, low-resolution brain electromagnetic tomography (LORETA [31]) was performed. This method has been widely described and used in the literature; here we use it in order to obtain likely source estimations for the time window in which significant effects were reported. LORETA source estimates were generated by means of Brain-Vision Analyzer 2 (for a similar approach, see, [32], with the current density values provided for 2394 voxels in the gray matter and the hippocampus of a reference brain (MNI 305, Brain Imaging Centre, Montreal Neurologic Institute). As shown in [Fig 2C, 2D and 2E](#), the estimation for the comparison between the regulate and the attend condition in the 2500–3000 ms time window showed as the maximal source the occipital gyrus, the right middle frontal gyrus, the superior frontal gyrus, the precentral and postcentral gyrus, and the precuneus. Notably, these areas partially overlap with regions found to be active during regulation tasks in previous fMRI studies [3,15,16].





**Fig 2. Effect of strategy.** Grand average waveforms (A) at the frontal sites (indicated in C) and topographical distribution of the effect distancing minus attend (B); the first vertical line indicates the target onset; the following four vertical lines indicate the boundaries of the time windows for the analyses (1000, 1500, 2000, and 2500 ms, respectively); average activity within each time window is shown in (D). Between 2500 and 3000 ms after stimulus onset, there was a main effect of Strategy with a larger negativity for the distancing than the attend condition. (E) LORETA source reconstruction showed as the maximal source the occipital gyrus, the right middle frontal gyrus, the superior frontal gyrus, the precentral and postcentral gyrus, and the precuneus. Error bars indicate the standard error of the mean, asterisks significant differences.

<https://doi.org/10.1371/journal.pone.0209461.g002>

**Effects of regulation on pictures and words.** Pictures and words elicit quite different electrophysiological patterns, both in terms of evoked component and response amplitude. Therefore, the two types of target were analyzed separately. In both cases, two analyses were run: First, we compared the unpleasant and neutral stimuli in the attend-strategy condition in order to identify the electrophysiological response to emotional stimuli. Second, we tested whether the application of a strategy affected the emotional response. To do that, we compared differential waves of targets in the two strategies; specifically, for each strategy the waves of unpleasant targets were subtracted to those of neutral targets and the comparison occurred between subtracted waves. Such analyses were run using the same electrodes groups and the same time windows adopted in the first analysis in which we estimated the emotional effects for the targets in the attend condition only.

## Pictures

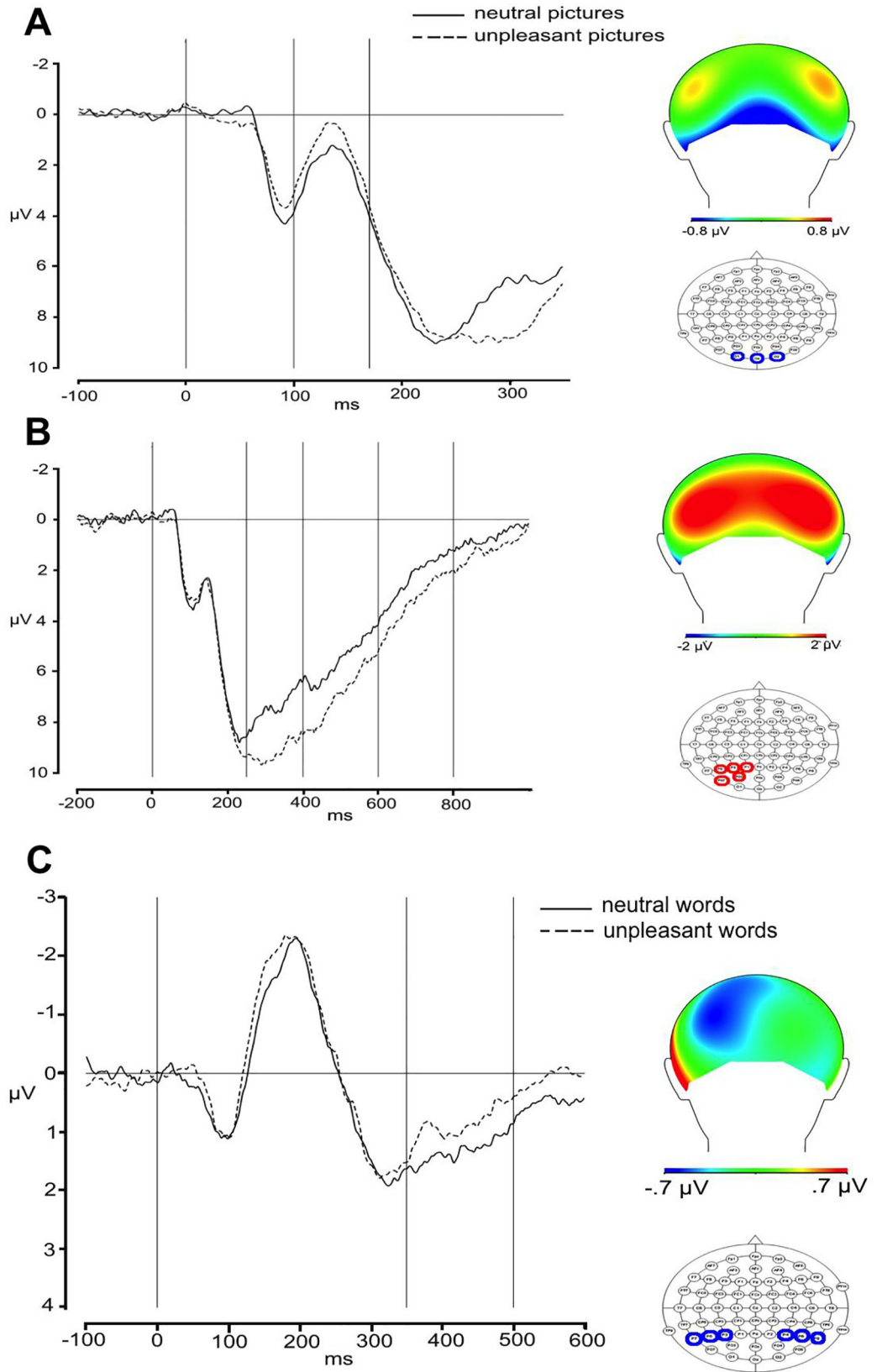
**Effect of content for pictures.** *Early Negativity.* The inspection of grand-averages shows that, at occipital sites, in visual related areas, unpleasant pictures differ very early from neutral pictures, with the former being more negative than the latter (see Fig 3). For its distribution and time dynamic, this negativity resembles a N170. Previous studies reported an emotional modulation of N170 component for emotional facial expressions [33,34] as well as for emotional pictures [35]. Another possible interpretation of this negativity might be in terms of Early Posterior Negativity (EPN). Although its time dynamic (before 200 ms) is a bit faster than that usually associated with such component, a similar time dynamic has been previously reported [36]. The statistical analysis conducted in the 100-170ms time window on a group of occipital channels (O1, Oz, O2) shows a maximal pronounced effect. A one-way ANOVA with the Emotional content (negative vs neutral) of the stimulus as within-participant factor showed the effect to be significant ( $F(1,29) = 6.40, p = .01$ ), with negative stimuli ( $1.4\mu\text{V}$ ) being less positive than neutral ones ( $2.2\mu\text{V}$ ). See Fig 3A.

*Late Positivity.* Negative pictures show a larger positivity on the posterior sites and a corresponding negativity on the centro-frontal area. The two conditions start to differ around 250 ms after target presentation and the positivity appears more accentuated on the left-posterior sites, lasting until approximately 800ms.

To test the statistical significance of the effects, six groups of electrodes were selected (Frontal Left: F5, F3, F1, FC5, FC3, FC1; Frontal Right: F6, F4, F2, FC6, FC4, FC2; Central Left: T7, C3, C1, CP5, CP3, CP1; Central Right: T8, C4, C2, CP6, CP4, CP2; Posterior Left: P5, P3, P1, PO7, PO3, O1; Posterior Right: P6, P4, P2, PO8, PO4, O2). The groups were created on the basis of the grand average waveforms reflecting the topography and temporal dynamics of the brain potential. Statistical analyses were run on 3 consecutive time windows. In all cases, we ran a  $2 \times 3 \times 2$  ANOVA with Emotional content (negative vs. neutral), Anterior-Posterior (frontal vs central vs posterior electrodes), and Hemisphere (left vs right) as within-participant factors. Central line was analyzed separately in a  $2$  (Emotional content: negative vs. neutral)  $\times$   $3$  (Anterior-Posterior: frontal [Fpz, Fz] vs. central [FCz, Cz, CPz] vs. posterior electrodes [Pz, Oz]) ANOVA, with both factors as within-participants. The Greenhouse-Geisser [37] correction was applied to all repeated measures with more than one degree of freedom (only corrected p values are reported).

*First time window– 250ms-400ms.* The main effect of Emotional content was significant ( $F(1,29) = 47.94, p < 0.001$ ) as well as the Emotional content by Anterior-Posterior interaction ( $F(2,58) = 38.78, p < 0.001$ ). Planned comparison showed that a difference between negative and neutral pictures only emerged on the posterior sites (negative:  $9.4\mu\text{V}$  vs neutral:  $7.6\mu\text{V}$ ,  $t = -2.00, p = 0.04$ ; frontal: negative:  $-6.4\mu\text{V}$  vs. neutral:  $-5.4\mu\text{V}$ ,  $t = 1.64, p > 0.1$ ; central: negative:  $0.1\mu\text{V}$  vs. neutral:  $0.1\mu\text{V}$ ,  $t < 1$ ; in this and the following planned comparisons p values were adjusted with Bonferroni method). The main effect of Anterior-Posterior was also significant ( $F(2,58) = 99.75, p < 0.001$ ). No further effect reached significance (Hemisphere:  $F = 1.77, p > 0.1$ ; Anterior-Posterior  $\times$  Hemisphere:  $F = 1.65, p > 0.2$ ; all other  $F_s < 1$ ). See Fig 3B. The analysis of central line showed a significant main effect of Anterior-Posterior ( $F(2,58) = 52.21, p = 0.001$ ); Anterior-Posterior also interacted with Emotional content ( $F(2,58) = 8.79, p = 0.001$ ). Planned comparison did not reveal any significant contrasts (all  $t_s < 1$ ; frontal: negative:  $-7.2\mu\text{V}$  vs neutral:  $-6.0\mu\text{V}$ ; central: negative:  $-3.9\mu\text{V}$  vs neutral:  $-3.4\mu\text{V}$ ; posterior: negative:  $5.2\mu\text{V}$  vs neutral:  $4.3\mu\text{V}$ ).

*Second time window– 400ms-600ms.* Again, the main effect of Emotional content was significant ( $F(1,29) = 58.11, p < .001$ ) as well as its interaction with Anterior-Posterior ( $F(2,58) = 6.43, p = .003$ ). Planned comparison, however, did not reveal any significant difference



**Fig 3. Effect of emotion for pictures.** Grand average waveforms for relevant sites and topographical distribution of the emotional effect (negative minus neutral) for pictures (A, B) and words (C). In each figure, the first vertical line in the plot of grand averages indicates the target onset, and the following vertical lines the boundaries of the time windows of analyses.

<https://doi.org/10.1371/journal.pone.0209461.g003>

(posterior: negative: 6.8  $\mu$ V vs neutral: 5.7  $\mu$ V;  $t = -1.50$ ,  $p > 0.1$ , central: negative: 1.5  $\mu$ V vs neutral: 1.1  $\mu$ V;  $t = -1.58$ ,  $p > 0.1$ ; frontal: negative: -5.1  $\mu$ V vs neutral: -4.6  $\mu$ V;  $t < 1$ ). The main effect of Longitude was significant ( $F(2,58) = 91.32$ ,  $p < 0.001$ ). No further effect reached significance (Hemisphere:  $F = 2.61$ ,  $p > 0.1$ ; Emotional content  $\times$  Anterior-Posterior:  $F = 1.62$ ,  $p > .2$ ; Anterior-Posterior  $\times$  Hemisphere:  $F = 1.91$ ,  $p > 0.1$ ; all other  $F_s < 1$ ). In the analysis of the central line, the effect of Anterior-Posterior was significant ( $F(2,58) = 35.02$ ,  $p < 0.001$ ). No further effect reached significance (Emotional content:  $F < 1$ ; Emotional content  $\times$  Anterior-Posterior:  $F = 1.50$ ,  $p > 0.2$ ). See Fig 3C

*Third time window– 600ms–800ms.* The main effect of Emotional content was significant ( $F(1,29) = 33.61$ ,  $p < 0.001$ ), as well as its interaction with Hemisphere ( $F(1,29) = 7.95$ ,  $p = 0.008$ ). Also the three-way interaction among Emotional content, Anterior-Posterior, and Hemisphere approached significance ( $F(2,58) = 3.19$ ,  $p = 0.07$ ). Planned comparisons showed that negative and neutral pictures differed at left central sites (negative: 1.5  $\mu$ V vs neutral: 0.5  $\mu$ V,  $t = -2.49$ ,  $p = 0.01$ ; no further comparison reached significance). The main effect of Anterior-Posterior was also significant ( $F(2,58) = 31.06$ ,  $p < 0.001$ ), as well as its interaction with Hemisphere ( $F(2,58) = 4.72$ ,  $p = 0.02$ ). No further effect reached significance (Hemisphere:  $F = 2.8$ ,  $p > 0.1$ , Emotional content  $\times$  Hemisphere  $F < 1$ ). In the analysis of the central line, the effect of Anterior-Posterior was significant ( $F(2,58) = 11.10$ ,  $p < 0.001$ ). No further effect reached significance (Emotional content:  $F < 1$ ; Emotional content  $\times$  Anterior-Posterior:  $F = 2.22$ ,  $p > 0.1$ ).

**Effect of regulation on pictures.** *Early Negativity.* The one-way ANOVA with Regulation (distancing vs attend) as a within-participant factor showed no significant effect ( $F < 1$ ). To further ascertain that the application of strategy does not modulate the effect we reported (effect of regulation), a 2  $\times$  2 ANOVA on un-subtracted waves was run with Regulation (distancing vs attend) and Emotional content (negative vs. neutral) as within-participants factor. The main effect of Emotional content was significant ( $F(1,29) = 9.63$ ,  $p = .004$ ). No further effect reached significance (Regulation:  $F = 3.86$ ,  $p > 0.05$ ; Regulation  $\times$  Emotional content:  $F < 1$ ). The absence of an interaction, together with the absence of any effect in the analysis of the differential waves, clearly indicates that the early responses elicited by negative pictures cannot be regulated through the application of an explicit strategy.

*Late Positivity.* For each time window a 2  $\times$  3  $\times$  2 ANOVA was run with Regulation (distancing vs attend), Anterior-Posterior (frontal vs. central vs posterior) and Hemisphere (left vs right) as within-participant factors. The central line was analyzed separately in a 2 (negative vs neutral)  $\times$  3 (frontal vs. central vs. posterior) ANOVA, with both factors as within-participants.

*First time window– 250ms–400ms.* The main effect of Regulation approached significance ( $F(1,29) = 3.19$ ,  $p = 0.08$ ). Regulation significantly interacted with Anterior-Posterior ( $F(2,58) = 5.78$ ,  $p = 0.001$ ). The three way interaction was also significant ( $F(2,58) = 5.12$ ,  $p = 0.002$ ). Planned comparisons showed differences in the posterior left (distancing: 0.79  $\mu$ V vs attend: 1.74  $\mu$ V,  $t = 2.12$ ,  $p = 0.04$ ) and frontal right sites (distancing: 0.14  $\mu$ V vs attend: -1.12  $\mu$ V,  $t = -2.52$ ,  $p = 0.01$ ). The main effect of Anterior-Posterior was significant ( $F(2,58) = 18.71$ ,  $p < 0.001$ ), whereas Hemisphere approached significance ( $F(1,29) = 4.06$ ,  $p = 0.06$ ). No further effect reached significance (Regulation  $\times$  Hemisphere:  $F = 1.83$ ,  $p > 0.1$ ; Anterior-Posterior  $\times$  Hemisphere:  $F = 1.36$ ,  $p > 0.2$ ).

The analysis of the central line shown main effects of Regulation ( $F(1,29) = 6.68, p = 0.01$ ) and Anterior-Posterior ( $F(2,58) = 4.07, p = 0.03$ ). The Regulation by Anterior-Posterior interaction was also significant ( $F(2,58) = 6.18, p = 0.008$ ). Planned comparisons showed that the attend condition was more negative than the distancing condition in the frontal site (distancing:  $-0.06 \mu\text{V}$  vs attend:  $-1.18 \mu\text{V}$ ,  $t = -2.11, p = 0.04$ ); also central sites approached significance ( $t = -1.8, p > 0.07$ ). No difference emerged posteriorly ( $t = 1.26, p > 0.2$ ).

*Second time window—400ms-600ms.* The main effect of Regulation approached significance ( $F(1,29) = 3.32, p = 0.08$ ), as well as the two-way interaction between Regulation and Hemisphere ( $F(1,29) = 3.24, p = 0.08$ ), and the three-way interaction among Regulation, Anterior-Posterior, and Hemisphere ( $F(2,58) = 3.05, p = 0.07$ ). The Regulation by Anterior-Posterior was significant ( $F(2,58) = 6.52, p = 0.01$ ). Planned comparisons for all the sites shown that the distancing and the attend condition differed at posterior left (distancing:  $0.21 \mu\text{V}$  vs attend:  $1.36 \mu\text{V}$ ,  $t = 2.53, p = 0.04$ ) and frontal right sites (distancing:  $0.56 \mu\text{V}$  vs attend:  $-0.73 \mu\text{V}$ ,  $t = -2.61, p = 0.01$ ). The other effects were not significant (Anterior-Posterior:  $F = 2.32, p > 0.1$ ; Anterior-Posterior x Hemisphere:  $F = 1.48, p > 0.2$ ). The analysis of the central line shown a main effect of Regulation ( $F(1,29) = 9.87, p = 0.003$ ) and a Regulation by Anterior-Posterior interaction ( $F(2,58) = 5.001, p = 0.01$ ). Planned comparisons showed that the attend condition was more negative than the distancing condition in the central site (distancing:  $0.37 \mu\text{V}$  vs attend:  $1.28 \mu\text{V}$ ,  $t = -2.08, p = 0.04$ ); also frontal sites approached significance (distancing:  $-0.78 \mu\text{V}$  vs attend:  $0.40 \mu\text{V}$ ,  $t = -1.76, p = 0.08$ ). No difference emerged posteriorly ( $t = 1.02, p > 0.3$ ).

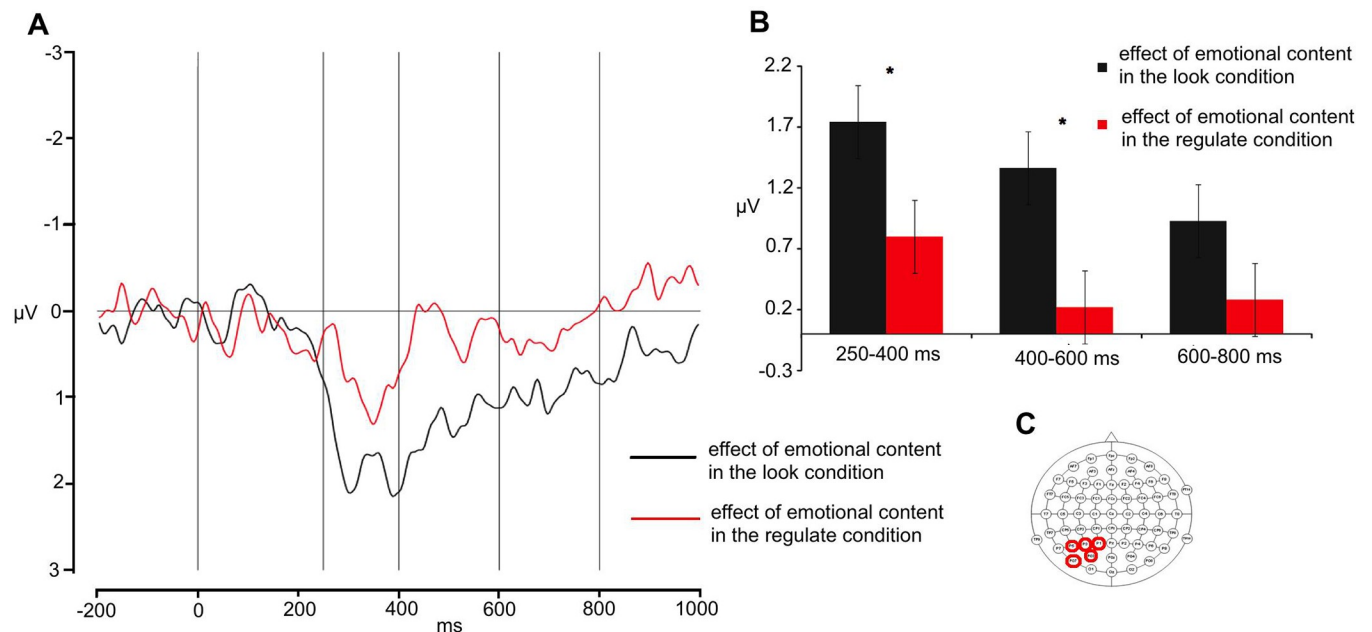
*Third time window—600ms-800ms.* The Regulation by Hemisphere interaction approached significance ( $F(1,29) = 3.56, p = 0.06$ ). The three-way interaction among Regulation, Anterior-Posterior, and Hemisphere was significant ( $F(2,58) = 5.72, p = 0.01$ ). Planned comparisons revealed that, at this point, the distancing and attend condition only differed at the frontal right site (attend  $0.38 \mu\text{V}$  vs attend:  $-0.91 \mu\text{V}$ ,  $t = -2.35, p = 0.02$ ). In the analysis, no further effect reached significance (Regulation x Anterior-Posterior:  $F = 1.48, p > 0.2$ ; all other  $F_s < 1$ ). The analysis of the central line showed a main effect of Anterior-Posterior ( $F(1,29) = 5.26, p = 0.02$ ). No further effect reached significance (Regulation:  $F = 2.51, p > 0.1$ , Regulation x Anterior-Posterior:  $F < 1$ ). See Fig 4A, 4B and 4C.

## Words

**Effect of content for words.** *Early negativity.* The inspection of grand-averages seems to show tiny differences between emotional and neutral stimuli. A larger negativity for emotional than neutral stimuli is visible on the parieto-temporo-occipital sites, in areas related with language processing, starting approximately 350 ms after target onset. For its distribution and polarity, such effect resembles an EPN (see [38] for similar results). To test its statistical significance, we run an analysis on two groups of electrodes (posterior-left: P7, P5, P3, O1; posterior-right: P8, P6, P4, O2), which we selected on the basis of the grand average waveforms reflecting the topography and temporal dynamics of the brain potential (for a similar selection, [38]). A 2 x 2 ANOVA with Emotional content (negative vs neutral) and Hemisphere (left vs. right) as within-participants factor was run on mean EEG amplitudes in the 350ms-500ms time window. The analysis showed a main effect of emotional content, with negative words producing more negativity than neutral words ( $1.71 \mu\text{V}$  vs  $2.17 \mu\text{V}$ ,  $F(1,29) = 4.23, p = 0.04$ ). No further effect reached significance (both  $F_s < 1$ ).

*Late Positivity.* The electrophysiological data do not show any larger positivity for emotional than neutral stimuli, showing no evidence for the LPP in any area of the scalp. To ascertain the absence of the LPP, statistical analyses were run on three groups of electrodes—i.e., left





**Fig 4. Effect of regulation for pictures.** Grand average waveforms (A) at relevant sites (indicated in C) of the effect of regulation for pictures. The first vertical line indicates the target onset; the following four vertical lines indicate the boundaries of the time windows for the analyses (250, 400, 600, and 800 ms, respectively); average activity within each time window is shown in (B). Error bars indicate the standard error of the mean, asterisks significant differences.

<https://doi.org/10.1371/journal.pone.0209461.g004>

(CP3, P1, P5, PO3), central (CPz, Pz), and right (CP3, P1, P5, PO3)—on which, according to the literature, the LPP is maximal (e.g., Citron, 2012; Herbert et al., 2008). The 2 (Emotional content: negative vs neutral) x 3 (Topography: left vs. central vs. right) ANOVA on the 500–700 ms time window showed no significant effect (Topography:  $F = 2.96$ ,  $p > 0.06$ ; all other  $F_s < 1$ ,  $p_s > 0.5$ ). See Fig 3.

**Effect of regulation on words.** The 2 (Regulation: distancing vs attend) x 2 (Hemisphere: left vs. right) ANOVA showed no significant effect (Regulation:  $F < 1$ ; Regulation x Hemisphere:  $F = 3.2$ ,  $p > 0.08$ ; Hemisphere:  $F = 1.93$ ,  $p > 0.1$ ). The result was further confirmed by the 2 (Regulation: distancing vs attend) x 2 (Emotional content: negative vs neutral) x 2 (Hemisphere: left vs. right) ANOVA we ran on un-subtracted waves, that showed only a main effect of Emotional content ( $F(1,29) = 5.40$ ,  $p = 0.02$ ) (Emotional content x Hemisphere:  $F = 2.16$ ,  $p > 0.1$ , all other  $F_s < 1$ ). The absence of any effect of regulation suggests that the application of a regulation strategy does not have any effect on the first electrophysiological response to emotional written stimuli.

## Discussion

This study provides behavioral and physiological evidence on the possibility to regulate emotional pictures and words stimuli by distancing. At the behavioral level, all participants were able to regulate the negative stimuli presented. Participants were able to regulate both the arousal and the valence of negative pictures in such a way as to reduce their emotional impact (decreased arousal, effect magnitude of  $[Distancing_{(negative\ pictures)} - Attend_{(negative\ pictures)}] = -0.42$  points), and to decrease their negativity (increased valence,  $+0.32$ ). While the regulation of pictures is in line with previous findings and confirms them [17,39–41], the novelty of the study is the demonstration that negative words can be regulated in both the arousal and the valence dimensions by using the strategy of distancing. Arousal decreased (effect magnitude of



[Distancing<sub>(negative words)</sub>—Attend<sub>(negative words)</sub>] = -0.73 points) and valence increased (+0.35) as an effect of strategy. To our knowledge this is the first time that emotional words are regulated in both arousal and valence by the use of distancing. This finding has some relevant implications. First, we constantly use words to regulate our emotions that are elicited when talking with others; second, we may want to regulate others' emotions by using words. Consider the example of what happens during social interactions. Understanding how we regulate linguistic stimuli is of fundamental importance in order to understand and possibly maximize how to regulate emotions. Moreover, previous studies rarely took into account both arousal and valence (see for an exception [15], and [22]). This is especially true in the case of words. We demonstrated separate behavioral effects of regulation on both arousal and valence.

A second finding is that distancing can be indeed an effective strategy for regulating both words and pictures and both emotional dimensions are comparable to other well studied strategies such as reappraisal or distraction. This result is important for two reasons. First, distancing is a commonly used strategy that does not require any particular cognitive effort (i.e., reinterpreting the meaning of the stimulus, or engaging in a distracting task). Clinicians have long reported the use of distancing-like strategies (e.g., isolation of affect, experiential avoidance, behavioral avoidance, dissociation) to protect ourselves from unbearable life events we cannot avoid or escape from. Second, from a methodological point of view, having shown that distancing is effective in regulating emotions opens the possibility of using such a strategy in studies in which more complex strategies may be difficult to use. Also, the fact that distancing is effective for both pictures and words implicates that this strategy can be successfully used in different situations independently of the nature of the emotional stimuli (linguistic, pictorial, etc). This may also indicate that distancing is modality independent and that it may act by blocking the emotional impact of stimuli without affecting the meaning of the stimuli themselves. This is very different from other strategies (e.g., reappraisal) that change the meaning of the stimuli in order to affect their emotional impact. Future studies may want to compare distancing and reappraisal strategies to understand their effect on different aspects of the elaboration of emotional stimuli.

In this study, ERPs were recorded to identify neural markers of the regulation process. Before analyzing the signal associated with the regulation of pictures and words, we analyzed the signal relative to the implementation of the strategy (i.e., in the time window when strategies are probed) as the first temporal event occurring during each trial. Notably, only a few experiments explored the effect of strategy [23–25], as they commonly focused on the effect of regulation (during stimulus presentation). We found that when participants applied the distancing strategy there was a significant long-lasting negativity over frontocentral electrodes starting approximately 2.5 s after the strategy presentation and lasting until the target appeared: the negativity was larger for the regulate than for the attend condition and was not modulated by the to-be-regulated stimulus, i.e., it was equal for both pictures and words. We interpreted the effect as a Stimulus-Preceding Negativity (SPN) that occurs before the execution of a task (regulate the response of the following emotional stimuli in our case). SPN has been reported by previous experiments investigating the electrophysiological response to strategy implementation [23,25], and has been interpreted as reflecting enhanced attentional orienting to and anticipation of impending stimuli. This negativity may be also related to what a previous fMRI experiment found when analyzing the effect of strategy (more activation compared to the no strategy condition) (see [15,16]). Previous studies showed that the regulation of unpleasant stimuli, may be related to the activity of frontal regions (e.g. lateral and medial frontal gyri, pre-supplementary motor area, and cingulate cortex; see [15,16]). Dipole reconstruction confirmed that the source of this effect may involve large portion of the lateral and medial frontal cortex. This is in line with previous neuroimaging findings suggesting that

down-regulation of unpleasant emotions activate prefrontal and cingulate regions (for a review, see [3]). We also found portions of the precuneus and of the occipital lobe not reported in previous fMRI studies. Future studies may want to better separate the role of these regions. Building on our previous findings, we suggest that beside the type of cognitive strategy used, a circuit involving the lateral and medial portions of the frontal cortex (but also extending to medial parietal and occipital regions), are responsible for the selection and implementation of the strategy (effect of strategy).

In order to assess possible differences between types of stimuli, the effect of regulation was also investigated through separate analyses for pictures and words. As expected, in the attend condition, pictures showed early and late modulations previously observed in study with emotional stimuli. Unpleasant pictures elicited an early negativity within 200 ms and maximal at occipital sites, with a larger negativity for unpleasant than pleasant stimuli; this component was followed by a larger positivity (i.e., LPP) for negative than neutral stimuli starting ~250 ms after target onset and lasting until ~800 ms after target onset; the positivity was clearly visible on the posterior sites and had a corresponding negativity on the centro-frontal area. The pattern of results is consistent with previous findings [35,42].

A potential interpretation of our early negative component is in terms of N170, which has been reported to be sensitive to the pictures emotional content [35,43]. In line with a more general interpretation of early negativities in the emotional literature, a modulation of N170 has been interpreted in relation to a selective categorization and attention mechanism that is involved in the detection of salient emotional stimuli (such as faces, objects, etc.) to pay attention to for further processing [35,43–45]. The early negativity, however, might be also interpreted in terms of EPN. Usually, this component has a slightly slower time dynamic, being visible ~200–300 ms after target onset, but an early EPN starting 150 ms after target onset has been also reported by Junghofer et al. [36] (note that these authors used a shorter presentation of pictures that might have anticipated the EPN). The EPN has been interpreted as indexing the selective attention, which is highly sensitive to the stimulus emotionality [35–45]. This early activity might reflect rapid amygdala processing of unpleasant information and increased engagement of autonomic arousal towards salient stimuli in visual related areas [46–48].

Our study showed that negative pictures modulated the early negative components, and that these components are not modulated by the regulation strategy. This may be due to the attentive nature of this component that is necessarily elicited by emotional stimuli, nor subject to cognitive control neither to eventual modulation by the strategy. Previous experiments clarified that early components may be task-independent, as their effect is not modulated by the depth of processing [49], the emotional nature of the task [50], or the self-referentiality of the emotional stimulus [51]. This suggests that these components index automatic, implicit processing of emotion [52]. Scholars agree on the fact that emotion regulation involves a process of early emotional reactivity (mainly automatic), as well as later voluntary inhibitory control [53].

The LPP is typically increased by emotional compared to neutral visual stimuli [19,44,54,55] and reflects enhanced processing and attention to emotional salient stimuli [54]. Larger LPP amplitudes are also correlated with increased arousal [54]. Several studies showed that the LPP can be modulated by reappraisal, showing larger deflections when up-regulating [23] and reduced deflections when down-regulating the emotional response [12,19,22,23,55–57]. The neural generators of the LPP are thought to be the extrastriate visual system and emotion-related structures such as amygdala [58], and may reflect stronger functional connectivity between occipital cortex and frontal areas [59]. Our study confirms this modulation of LPP as an effect of down-regulating the content of emotional pictures (significant difference in the central line electrodes); this is mainly visible in the first stages of the component (i.e., between

250 ms and 600 ms after target presentation), which showed the maximal LPP reduction at multiple sites. Thus, when comparing the impact of the emotional content on the stimuli in the distancing vs. attend condition, one may immediately note the drastic LPP reduction (left-posterior region, first time window [250–400 ms]: effect of emotional content (negative—neutral) in the REGULATE condition: 0.79  $\mu$ V vs. effect of emotional content (negative—neutral) in the Attend condition: 1.74  $\mu$ V; second time window [400–600 ms]: effect of emotional content (negative—neutral) in the REGULATE condition: 0.21  $\mu$ V vs. effect of emotional content (negative—neutral) in the Attend condition: 1.36  $\mu$ V). Previous studies using ERPs reported that the LPP amplitude is affected by instructions to down-regulate the emotional responses due to negative stimuli [12,20,21,55,56,60]. These studies involved participants using cognitive strategies such as reappraisal, suppression and distraction, and showed regulation of both subjective ratings and LPP. Our study is the first to show an effect of modulation over LPP due to a not commonly studied strategy defined as distancing. Although distancing was originally proposed by Gross [53] to be a cognitive strategy, we believe that it should be considered not a pure cognitive strategy (no explicit thought generation, nor rethinking effort), but rather an experiential strategy as it involves a different way of relating to the stimuli [1,2,61]. Research has shown that adopting a mindful, or unemotional self-observation attitude, can be a useful means to reduce emotional reactivity to negative information comparable to, or even more efficient than, cognitive strategies [61–63].

Unpleasant linguistic stimuli elicited a larger negativity for negative than for neutral stimuli; for its timing and occipital-temporo-parietal distribution, we interpreted such negativity as an EPN related to the processing of linguistic stimuli. The EPN for emotional words has been repeatedly reported across different tasks: silent reading [38,64,65], lexical decision [49,52,66], written word identification [67] and Stroop [68]. Our study confirms previous findings and is in line with the view that the EPN is task-independent and may be elicited by the simple passive exposure to written material. Moreover, the failure to find any modulation of the effect of regulation of such component parallels our results with pictures and suggests that the EPN indexes early automatic processing of emotion [52, 42]. A second possible explanation for the absence of a modulation of the EPN may be that the EPN is a smaller component (circa 0.80 mV) as compared to LPP (1.80 mV). This reduced size may have clouded the effect of regulation.

Word stimuli, however, did not show any LPP. The absence of such component may be due to our experimental design. The literature on emotional words shows mixed and contrasting finding on the LPP: while some studies usually reported larger LPP for emotional than neutral words [67,69,70,49], other studies reported the opposite pattern [71], and others no difference at all between emotional and neutral words [67]. Indeed, LPP amplitude is modulated by different dimensions as type of task—with larger amplitude when a more in-depth processing of the stimulus is required [49]—and the emotional self-relevance of the content—with larger amplitude when stimuli are referred to the self rather than to others [51]. A further reason for the absence of the LPP with word stimuli may be due to the lesser power words have to induce emotional responses. In a previous experiment with fMRI, Kensinger and Schacter [72] reported lower statistical power and therefore more circumscribed activations for words than pictures. No effect of modulation for LPP was visible. The modulation of LPP when regulating linguistic stimuli was observed only by Deveney and Pizzagalli [6] probably due to the nature of the task used that combined visual and linguistic stimuli in sequence.

Some limitations of the present study should be acknowledged. First, when words are considered, ERPs data failed to show any regulation effect, representing a dissociation between behavioral and ERP measures for negative linguistic stimuli. It is not clear whether the lack of ERP modulation was a limitation of the current task design (selection of stimuli, valence and

arousal power, etc), or whether these findings indicate that ERPs might be less sensitive for detecting the effects of regulation over such class of stimuli. We believe the emotional effects of linguistic stimuli are harder to detect. Future studies may focus on linguistic stimuli only by using more arousing and negatively valenced stimuli to increase the possibility of detecting ERP effects. Although we used the good spatial resolution of 60 electrodes montage, a higher spatial resolution may have help finding finer grained differences. Another possible limitation of the experiment is that the two categories of stimuli are not perfectly matched for valence and arousal, being words more arousing and more valenced than pictures. For this and other reasons, any direct EEG comparison between the two categories was avoided. We also believe that such contrast may be difficult to interpret because of the large differences between the neural mechanisms involved between the two categories of stimuli.

These limitations notwithstanding, the present study provides strong behavioral evidence that linguistic stimuli can be regulated and this may pave the way to better understand how our language can be used not only to catch emotional meaning, but also to understand how we regulate emotions conveyed by words. In everyday life we are constantly engaged in social interactions and words are the primary mean we use to express emotional meaning. To prevent excessive interference with ongoing cognitive and social abilities necessary to interact with others, and to avoid being overwhelmed by emotions, incoming linguistic stimuli sometimes must be regulated [73]. This study further supports the possibility that humans may use distancing to regulate emotional pictures and words.

## Author Contributions

**Conceptualization:** Alessandro Grecucci, Simone Sulpizio, Remo Job.

**Data curation:** Alessandro Grecucci, Simone Sulpizio, Elisa Tommasello.

**Formal analysis:** Alessandro Grecucci, Simone Sulpizio.

**Investigation:** Alessandro Grecucci.

**Methodology:** Alessandro Grecucci, Simone Sulpizio.

**Project administration:** Alessandro Grecucci, Simone Sulpizio, Remo Job.

**Supervision:** Alessandro Grecucci, Francesco Vespignani, Remo Job.

**Writing – original draft:** Alessandro Grecucci, Simone Sulpizio, Remo Job.

**Writing – review & editing:** Alessandro Grecucci, Simone Sulpizio, Francesco Vespignani, Remo Job.

## References

1. Grecucci A, Chiffi D, Di Marzio F, Frederickson J, Job R. Anxiety and its regulation: Neural mechanisms and regulation techniques according to the Experiential-Dynamic approach. Durbano F, Marchesi B. (Ed) *New Developments in Anxiety Disorders*. InTech publishing. 2016.
2. Grecucci A, Frederickson JJ, Job R. Editorial: Advances in Emotion Regulation: from neuroscience to psychotherapy. *Front Psychol*. 2017; 8: 985. <https://doi.org/10.3389/fpsyg.2017.00985> PMID: 28680409
3. Buhle JT, Silvers JA, Wager TD, Lopez R, Onyemekwu C, Kober H, et al. Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. *Cereb Cortex*. 2014; 24(11): 2981–90. <https://doi.org/10.1093/cercor/bht154> PMID: 23765157
4. Dadomo H, Grecucci A, Giardini I, Ugolini E, Carmelita A, Panzeri M. Schema Therapy for Emotional Dysregulation: Theoretical Implication and Clinical Application. *Front Psychol*. 2016; 7.
5. Freud S. *Introductory Lectures on Psycho-Analysis (PFL 1, Complete Psychological Works of Sigmund Freud)*. Liveright. 1992.

6. Deveney CM, Pizzagalli DA. The cognitive consequences of emotion regulation: an ERP investigation. *Psychophysiology*. 2008; 45(3): 435–44. <https://doi.org/10.1111/j.1469-8986.2007.00641.x> PMID: 18221443
7. Speed BC, Levinson AR, Gross JJ, Kiosses DN, Hajcak G. Emotion regulation to idiographic stimuli: Testing the Autobiographical Emotion Regulation Task. *Neuropsychol*. 2017; 3932(17): 30161–6.
8. Banks SJ, Eddy KT, Angstadt M, Nathan PJ, Phan KL. Amygdala-frontal connectivity during emotion regulation. *Soc Cogn Affect Neurosci*. 2007; 2(4): 303–12. <https://doi.org/10.1093/scan/nsm029> PMID: 18985136
9. Kanske P, Plitschka J, Kotz SA. Attentional orienting towards emotion: P2 and N400 ERP effects. *Neuropsych*. 2011 49(11): 3121–9.
10. Ochsner KN, Ray RD, Cooper JC, Robertson ER, Chopra S, Gabrieli JD, et al. For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *Neuroim*. 2004; 23(2) 483–99.
11. Hajcak G, Nieuwenhuis S. Reappraisal modulates the electrocortical response to negative pictures. *Cogn Affect Behav Ne*. 2006; 6: 291–297.
12. Schönfelder S, Kanske P, Heissler J, Wessa M. Time course of emotion-related responding during distraction and reappraisal. *Soc Cogn Affect Neurosci*. 2014; 9(9): 1310–1319. <https://doi.org/10.1093/scan/nst116> PMID: 23988760
13. Kross E, Ayduk O. Self-Distancing: Theory, Research, and Current Directions. In: Olson J.M., editor. *Advances in Experimental Social Psychology*. Academic P. Elsevier Inc. 2017.
14. Grecucci A, Giorgetta C, Bonini N, Sanfey AG. Living emotions, avoiding emotions: behavioral investigation of the regulation of socially driven emotions. *Front Psychol*. 2013c; 3: 616.
15. Grecucci A, Giorgetta C, van't Wout M, Bonini N, Sanfey AG. Reappraising the ultimatum: an fMRI study of emotion regulation and decision making. *Cereb Cortex*. 2013b; 23(2): 399–410.
16. Grecucci A, Giorgetta C, Bonini N, Sanfey A. Reappraising social emotions: the role of inferior frontal gyrus, temporo-parietal junction and insula in interpersonal regulation. *Front Hum Neurosci*. 2013c; 7: 523.
17. Schupp HT, Cuthbert BN, Bradley MM, Cacioppo JT, Ito T, Lang PJ. Affective picture processing: the late positive potential is modulated by motivational relevance. *Psychophysiology*. 2000; 37: 257–261. PMID: 10731776
18. Moser JS, Hajcak G, Bukay E, Simons RF. Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology*. 2006; 43: 292–296. <https://doi.org/10.1111/j.1469-8986.2006.00402.x> PMID: 16805868
19. Foti D, Hajcak G. Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. *J Cog Neurosci*. 2008; 20: 977–988.
20. Paul S, Simon D, Kniesche R, Kathmann N, Endrass T. Timing effects of antecedent- and response-focused emotion regulation strategies. *Biol Psychology*. 2013; 94(1): 136–142.
21. Gan S, Yang J, Chen X, Yang Y. The electrocortical modulation effects of different emotion regulation strategies. *Cog Neurodynamics*. 2015; 9(4): 399–410.
22. Qi S, Li Y, Tang X, Zeng Q, Diao L, Li X, et al. The temporal dynamics of detached versus positive reappraisal: An ERP study. *Cogn Affect Behav Ne*. 2017; 17(3): 516–527.
23. Moser JS, Kropfing J, Dietz J, Simons RF. Electrophysiological correlates of decreasing and increasing emotional responses to unpleasant pictures. *Psychophysiology*. 2009; 46(1): 17–27. <https://doi.org/10.1111/j.1469-8986.2008.00721.x> PMID: 18992073
24. Shafir R, Schwartz N, Blechert J, Sheppes G. Emotional intensity influences pre-implementation and implementation of distraction and reappraisal. *Soc Cogn Affect Neurosci*. 2015; 10(10): 1329–37. <https://doi.org/10.1093/scan/nsv022> PMID: 25700568
25. Thiruchselvam R, Blechert J, Sheppes G, Rydstrom A, Gross JJ. The temporal dynamics of emotion regulation: an EEG study of distraction and reappraisal. *Biol Psychology*. 2011; 87(1): 84–92.
26. Moser JS, Dougherty A, Mattson WI, Katz B, Moran TP, Guevarra D, et al. Third-person self-talk facilitates emotion regulation without engaging cognitive control: Converging evidence from ERP and fMRI. *Sci Rep*. 2017; 7(1): 4519. <https://doi.org/10.1038/s41598-017-04047-3> PMID: 28674404
27. Lang PJ, Bradley MM, Cuthbert BN. International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical report A-8. 2008.
28. Montefinese M, Ambrosini E, Fairfield B, Mammarella N. The adaptation of the Affective Norms for English Words (ANEW) for Italian. *Behav Res Methods*. 2014; 46: 887–903. <https://doi.org/10.3758/s13428-013-0405-3> PMID: 24150921



29. Bradley MM, Lang PJ. Affective norms for English words (ANEW): Instruction manual and affective ratings (pp. 1–45). Technical Report C-1, The Center for Research in Psychophysiology, University of Florida. 1999.
30. Brunia CHM, van Boxtel GJM, Böcker KBE. Negative Slow Waves as Indices of Anticipation: The Bereitschaftspotential, the Contingent Negative Variation, and the Stimulus-Preceding Negativity, in Kappenman E. S. and Luck S. J., *The Oxford Handbook of Event-Related Potential Components*, Oxford University Press. 2012.
31. Pascual-Marqui RD, Michel CM, Lehmann D. Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. *Int J Psychophysiology*. 1994; 18(1): 49–65.
32. Yoder KJ, Decety J. Spatiotemporal neural dynamics of moral judgment: a high-density ERP study. *Neuropsychologia*. 2014; 60: 39–45. <https://doi.org/10.1016/j.neuropsychologia.2014.05.022> PMID: 24905282
33. Batty M, Taylor M. Early processing of the six basic facial emotional expressions. *Cog Brain Res*. 2003; 17(3): 613–620.
34. Righart R, de Gelder B. Rapid influence of emotional scenes on encoding of facial expressions: An ERP study. *Soc Cogn Affect Neurosci*. 2008; 3(3): 270–278. <https://doi.org/10.1093/scan/nsn021> PMID: 19015119
35. Schupp HT, Junghöfer M, Weike AI, Hamm AO. Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. *Neuroreport*. 2003a; 14: 1107–1110. <https://doi.org/10.1097/01.wnr.0000075416.59944.49> PMID: 12821791
36. Junghöfer M, Bradley MM, Elbert TR, Lang PJ. Fleeting images: A new look at early emotion discrimination. *Psychophysiology*. 2001; 38: 175–178. PMID: 11347862
37. Geisser S, Greenhouse S. On methods in the analysis of profile data. *Psychometrika*, 1959; 24: 95–112.
38. Herbert C, Junghöfer M, Kissler J. Event related potentials to emotional adjectives during reading. *Psychophysiology*. 2008; 45: 487–498. <https://doi.org/10.1111/j.1469-8986.2007.00638.x> PMID: 18221445
39. Bradley MM, Hamby S, Low A, Lang PJ. Brain potentials in perception: Picture complexity and emotional arousal. *Psychophysiology*, 2007; 44: 364–373. <https://doi.org/10.1111/j.1469-8986.2007.00520.x> PMID: 17433095
40. Carretié L, Hinojosa JA, Albert J, Mercado F. Neural response to sustained affective visual stimulation using an indirect task. *Exp Brain Res*, 2006; 174: 630–637. <https://doi.org/10.1007/s00221-006-0510-y> PMID: 16708242
41. Crawford LE, Cacioppo JT. Learning where to look for danger: Integrating affective and spatial information. *Psych Science*, 2002; 13: 449–453.
42. Schupp HT, Junghöfer M, Weike AI, Hamm AO. The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, 2001b; 41: 441–449.
43. Keil A, Müller MM, Gruber T, Wienbruch C, Stolarova M, Elbert T. Effects of emotional arousal in the cerebral hemispheres: a study of oscillatory brain activity and event-related potentials. *Clin Neurophysiology*. 2001; 112(11): 2057–2068.
44. Olofsson JK, Nordin S, Sequeira H, Polich J. Affective picture processing: an integrative review of ERP findings. *Biol psychology*, 2008; 77(3): 247–265.
45. Dolcos F, Cabeza R. Event-related potentials of emotional memory: encoding pleasant, unpleasant, and neutral pictures. *Cogn Affect Behav Ne*. 2002; 2: 252–263.
46. LeDoux JE. Emotion: Clues from the brain. *Annual Review of Psychology*. 1195; 46, 209–235.
47. Lithari C, Frantzidis CA, Papadelis C, Vivas AB, Klados MA, Ioannides AA, et al. Are females more responsive to emotional stimuli? A neurophysiological study across arousal and valence dimensions. *Brain Topography*. 2010; 23: 27–40. <https://doi.org/10.1007/s10548-009-0130-5> PMID: 20043199
48. Morris JS, Öhman A, Dolan RJ. Conscious and unconscious emotional learning in the human amygdala. *Nature*. 1998; 393: 467–470. <https://doi.org/10.1038/30976> PMID: 9624001
49. Schacht A, Sommer W. Time course and task dependence of emotion effects in word processing. *Cogn Affect Behav Ne*. 2009a; 9: 28–43.
50. Kissler J, Assadollahi R, Herbert C. Emotional and semantic networks in visual word processing: insights from ERP studies. *Prog Brain Res*. 2006; 156: 147–183. [https://doi.org/10.1016/S0079-6123\(06\)56008-X](https://doi.org/10.1016/S0079-6123(06)56008-X) PMID: 17015079
51. Herbert C, Pauli P, Herbert BM. Self-reference modulates the processing of emotional stimuli in the absence of explicit self-referential appraisal instructions. *Soc Cogn Affect Neurosci*. 2010; 2: 303–312.



52. Citron FMM. Neural correlates of written emotion word processing: a review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain Lang.* 2012; 122(3): 211–226. <https://doi.org/10.1016/j.bandl.2011.12.007> PMID: 22277309
53. Gross JJ. Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology.* 2002; 39(3): 281–291. PMID: 12212647
54. Cuthbert BN, Schupp HT, Bradley MM, Birbaumer N, Lang PJ. Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biol Psychol.* 2000; 52: 95–111. PMID: 10699350
55. Hajcak G, Nieuwenhuis S. Reappraisal modulates the electrocortical response to unpleasant pictures. *Cogn Affect Behav Ne.* 2006; 6: 291–297.
56. Hajcak G, Dunning JP, Foti D. Neural response to emotional pictures is unaffected by concurrent task difficulty. An event-related potential study. *Behav Neurosci.* 2007; 121: 1156–1162. <https://doi.org/10.1037/0735-7044.121.6.1156> PMID: 18085868
57. Sarlo M, Ubel S, Leutgeb V, Schienle A. Cognitive reappraisal fails when attempting to reduce the appetitive value of food: an ERP study. *Biol Psychol.* 2013; 94(3): 507–12. <https://doi.org/10.1016/j.biopsycho.2013.09.006> PMID: 24056130
58. Sabatinelli D, Lang PJ, Keil A, Bradley MM. Emotional perception: Correlation of functional MRI and event-related potentials. *Cereb Cortex.* 2007; 17: 1085–1091. <https://doi.org/10.1093/cercor/bhl017> PMID: 16769742
59. Moratti S, Saugar C, Strange BA. Prefrontal-occipitoparietal coupling underlies late latency human neuronal responses to emotion. *J Neurosci.* 2011; 31(47): 17278–86. <https://doi.org/10.1523/JNEUROSCI.2917-11.2011> PMID: 22114294
60. Moser JS, Most SB, Simons RF. Increasing negative emotions by reappraisal enhances subsequent cognitive control: A combined behavioural and electrophysiological study. *Cogn Affect Behav Ne.* 2010; 10: 195–207.
61. Grecucci A, De Pisapia N, Venuti P, Palladino MP, Job R. Baseline and strategic mindful regulation: behavioral and physiological investigation. *Plos One.* 2015; 10(1): e0116541. <https://doi.org/10.1371/journal.pone.0116541> PMID: 25590627
62. Farb N, Anderson A, Mayberg H, Bean J, McKeon D, Segal Z. Minding one's emotions: mindfulness training alters the neural expression of sadness. *Emot.* 2010; 10: 25–33.
63. Schmeichel B, Demaree H. Working memory capacity and spontaneous emotion regulation: High capacity predicts self-enhancement in response to negative feedback. *Emotion.* 2010; 10(5): 739–744. <https://doi.org/10.1037/a0019355> PMID: 21038959
64. Kissler J, Herbert C, Peyk P, Junghöfer M. Buzzwords: early cortical responses to emotional words during reading. *Psychol Sci.* 2007; 18(6): 475–480. <https://doi.org/10.1111/j.1467-9280.2007.01924.x> PMID: 17576257
65. Kissler J, Herbert C, Winkler I, Junghofer M. Emotion and attention in visual word processing: an ERP study. *Biol Psych.* 2009; 80(1): 75–83.
66. Schacht A, Sommer W. Emotions in word and face processing: Early and late cortical responses. *Brain Cogn.* 2009b; 69: 538–550.
67. Hinojosa JA, Méndez-Bértolo C, Pozo MA. Looking at emotional words is not the same as reading emotional words: Behavioural and neural correlates. *Psychophysiology.* 2010; 47: 748–757. <https://doi.org/10.1111/j.1469-8986.2010.00982.x> PMID: 20158677
68. Franken IH, Gootjes L, van Strien JW. Automatic processing of emotional words during an emotional Stroop task. *Neuroreport.* 2009; 20(8): 776–781. <https://doi.org/10.1097/WNR.0b013e32832b02fe> PMID: 19369909
69. Carretié L, Hinojosa JA, Albert J, López-Martín S, De La Gándara BS, Igoa JM, et al. Modulation of ongoing cognitive processes by emotionally intense words. *Psychophysiology.* 2008; 45: 188–196. <https://doi.org/10.1111/j.1469-8986.2007.00617.x> PMID: 17971056
70. Carretié L, Hinojosa JA, Lopez-Martin S, Tapia M. An electrophysiological study on the interaction between emotional content and spatial frequency of visual stimuli. *Neuropsychologia.* 2007; 45: 1187–1195. <https://doi.org/10.1016/j.neuropsychologia.2006.10.013> PMID: 17118408
71. Hinojosa JA, Carretié L, Valcarcel MA, Méndez-Bértolo C, Pozo MA. Electrophysiological differences in the processing of affective information in words and pictures. *Cogn Affect Behav Ne.* 2009; 9: 173–189.
72. Kensinger EA, Schacter DL. Processing emotional pictures and words: Effects of valence and arousal. *Cogn Affect Behav Ne.* 2006; 6: 110–126.
73. Kircanski K, Lieberman MD, Craske MG. Feelings Into Words: Contributions of Language to Exposure Therapy. *Psych Sci* 2012;. 23(10): 1086–1091.