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Research article

Event-related brain potential correlates of words' emotional valence irrespective of arousal and type of task

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ABSTRACT

Many Event-Related brain Potential (ERP) experiments have explored how the two main dimensions of emotion, *arousal* and *valence*, affect linguistic processing. However, the heterogeneity of experimental paradigms and materials has led to mixed results. In the present study, we aim to clarify words' emotional valence effects on ERP when arousal is controlled, and determine whether these effects may vary as a function of the type of task performed. For these purposes, we designed an ERP experiment with the valence of words manipulated, and arousal equated across valences. The participants performed two types of task: in one, they had to read aloud each word, written in black on a white background; in the other, they had to name the color of the ink in which each word was written. The results showed the main effects of valence irrespective of task, and no interaction between valence and task. The most marked effects of valence were in response to negative words, which elicited an Early Posterior Negativity (EPN) and a Late Positive Complex (LPC). Our results suggest that, when arousal is controlled, the cognitive information in negative words triggers a 'negativity bias', these being the only words able to elicit emotion-related ERP modulations. Moreover, these modulations are largely unaffected by the types of task explored here.

1. Introduction

On a biological level the use of emotional rather than neutral stimuli facilitates the rapid detection of salient events [1,2]. A wide range of experiments using pictures and faces supports this approach [3]. Additionally, not only salient biological stimuli, but also learned emotional stimuli, such as words, can enhance certain cognitive processes and behavioral responses in different contexts [4].

Most of the literature on the processing of emotional words has used Event-Related brain Potentials (ERP), as these provide the time course of such emotional and cognitive processes. Emotionally-laden words typically elicit Early Posterior Negativity (EPN), peaking around 200–300 ms after stimulus onset with temporo-occipital distribution and related to an automatic allocation of attentional resources [3]. Generally, emotional words elicit EPN, usually regardless of task demands [5], suggesting a critical arousal effect on this fluctuation. Its sources appear within the inferotemporal cortex, which is likely to be involved in directing attention towards motivationally relevant stimuli (e.g. [6]), in line with activation of the amygdala and the inferotemporal cortex during emotional processing [7].

At later latencies, emotional words elicit the centro-parietal Late Positive Complex (LPC), which usually appears after around 500–800 ms. It is thought to reflect sustained processes such as re-analysis, evaluation and memory encoding [8]. Importantly, the LPC seems modulated by task demands and stimulus valence, with significant differences in amplitude between negative and positive words [8]. Its sources seem to be located in the dorsolateral prefrontal cortex [9,10], typically involved in executive functions, working memory and decision making, though its role in emotional processing has recently been stressed (e.g., [11]).

As the above literature would suggest, the affective component of a word seems to be processed at two stages. At an early stage, EPN would reflect the processing of arousal by recruiting automatic neural networks. The specific sign of valence does not seem critical. At a later stage, words' emotional valence would modulate more controlled, evaluative, and cognitively demanding processes, indexed by the LPC. However, some studies have found that valence can differentially modulate EPN. For instance, a positivity bias has been reported, by virtue of which positive words elicit higher EPN amplitudes than negative ones [12,13]. In other cases, negative words seem unable to

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evoke EPN [14]. A recent study [15] reports no modulations at all by valence on either EPN or LPC components, when emotional origin (whether emotional reactions to words are automatic vs. reflective) is controlled. There is also a lack of consistency in findings concerning the way in which valence modulates the LPC: larger amplitudes having been found for positive (e.g., [12]) and for negative words (e.g. [16]). Furthermore, the LPC has been seen to be modulated by arousal, regardless of valence (e.g., [17]).

The reasons for these discrepancies remain unclear. In our view, one possible explanation is that the two main dimensions of emotion, *arousal* and *valence*, have rarely been treated as truly independent: experimental setups in which emotional and neutral words are equated in levels of arousal are noticeably lacking (for exceptions, see [15,18]). Another important reason is probably the use of different tasks (e.g., [18]). The range of tasks used encompasses silent reading, letter detection, lexical decision, or an emotional Stroop task. The purpose of the present study is to focus on valence, while controlling for arousal, and the extent to which ERP modulations in this regard may depend on the task performed.

To achieve this goal, words of the three emotional valences (positive, neutral, negative) were matched in arousal. Our participants performed two different experimental tasks. In one, they had to read aloud words written in black on white (reading aloud task, RA). The other consisted in an emotional Stroop task (ES), where participants had to name the color of the ink in which the words were printed. Both tasks involve automatic semantic processing, but the ES task also involves other processes, such as higher cognitive load and interference [19], while inducing anxiety and increasing arousal [20]. If ERP modulations for word valence vary as a function of task demands or arousal levels, our two tasks should display noticeable differences in this respect. Regarding valence effects on ERP itself, it is not possible to establish straightforward predictions of the results, considering the paucity of our design relative to the control of arousal for neutral words, and the specific tasks used.

2. Materials and methods

2.1. Participants

Twenty-four native Spanish speakers (mean age = 25.5; *SD* = 8.37, 17 females) participated in the study after informed consent. The study was developed in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Complutense University. All participants reported normal or corrected-to-normal vision and had no history of neurological or cognitive disorders or reading difficulty. They were right-handed, ranging from 30 to 100 (*M* = 83) according to the Edinburgh Handedness Inventory [21]. After the recording session, they filled out a STAI (State-Trait Anxiety Inventory) questionnaire [22] to discard out-of-normal state or trait anxiety. All subjects exhibited normal scores (mean state-anxiety = 71.5, *SD* = 9.8; mean trait-anxiety = 66.6, *SD* = 15.3).

2.2. Materials

The experimental materials consisted of 180 words from the Spanish adaptation of ANEW [23]: 60 positive, 60 negative and 60 neutral (half nouns, half adjectives). The average word valence was 7.46 (*SD* = 0.36) for positive, 2.29 (*SD* = 0.48) for negative, and 5.01 (*SD* = 0.56) for neutral, on a scale ranging from 1 to 9 (negative to positive). The arousal levels (again, on a scale from 1 to 9) were matched across valences, the mean arousal value always being the same: 5.03 (positive *SD* = 0.53, negative *SD* = 0.55, neutral *SD* = 0.52). During the experiment, each word appeared twice, once per task.

2.3. Procedure

The material was distributed in 6 blocks as a factorial combination of valence (positive, negative, neutral) and task (RA, ES). During the experiment, participants performed 3 consecutive blocks of the same task (counterbalancing the order of presentation of the three valences across subjects), followed by 3 blocks of the other task. The initial task was counterbalanced across participants. In the ES task, six different colors (on a white background) were used: red, green, blue, yellow, magenta, and orange. In the RA blocks, participants read aloud a series of words written in black on a white background. Every block contained 60 words of the same valence (positive, negative, or neutral).

Participants were seated in a quiet shielded chamber. Stimuli appeared on an LCD screen, with a visual angle between 0.8° and 4° width. Each trial began with an asterisk, shown for 500 ms. After an interstimulus interval (ISI) of 300 ms, a single word appeared for 300 ms, followed by 300 ms during which the screen was blank. Participants were instructed to name aloud the color in which the word appeared (ES task) or read the word (RA task), as fast as possible immediately after its presentation. The blank screen was followed by a fixation cross for 500 ms, and then a neutral sentence appeared word by word for a sentence-acceptability task within the framework of a different experiment [24]. This sequence lasted 4800 ms, and was followed by the initial asterisk of the next test item.

Before the experimental trials, participants performed 6-trial training. Because the two parts of the experiment (the different tasks) presumably involved different levels of arousal, sufficient time was left between the third and fourth blocks to reach baseline levels at the beginning of each part. During this time, participants filled in the handedness inventory. Then, instructions about the new procedure (ES task vs. RA task) were given, followed by 6-trial training before starting the last three blocks.

To measure the level of physiological arousal, the skin conductance response (SCR) was monitored throughout the experiment. A J + J Engineering I-330-C2 polygraph was connected to the index and middle fingers of the hand not used to respond in the sentence-acceptability task. Data were standardized among subjects to facilitate the comparison of SCR means across conditions: individual measures in μS were averaged for each participant separately. This grand mean was assigned a value of 1; the specific values for each task were calculated as a function of their standard deviations from the grand mean.

2.4. Electroencephalographic recording

The electroencephalogram (EEG) was recorded with 59 electrodes attached in a cap (Electro Cap International) in the standard 10/20 positions, plus the right mastoid (M2), all of them referenced to the left mastoid (M1). The electro-oculogram (EOG) was recorded with electrodes above and below the left eye (VEOG), and at the outer canthus of each eye (HEOG). Impedance values were below 3 kΩ. The signal was recorded with a bandpass from 0.01 to 30 Hz and a sampling rate of 250 Hz.

2.5. Data analysis

The continuous recording of EEG was divided into 1200-ms epochs, starting 200 ms before the onset of the word. Data were re-referenced offline to the average value of the whole-scalp electrodes. As participants had to speak aloud after the onset of the word, we removed muscular artifacts together with eye movements using a standard ocular-correction algorithm [25]: first, HEOG and VEOG signals, with bipolar referencing, were used for ocular artifact correction; thereafter, each ocular electrode signal was separated into the two channels involved in each (i.e., HEOG +, HEOG-, VEOG +, and VEOG-, separately) and used to determine facial muscular movements by referencing them to the common reference, and then used to correct muscular artifacts by