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.

KEYWORDS: Language, emotion, valence, ERP, EPN, LPC.

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 reanalysis, 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 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 inter-stimulus 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 applying the Gratton et al. [25] computation again. Other artefacts exceeding +/- 100 µV were rejected.

For statistical analyses (ANOVAs), we grouped the electrodes into three brain regions of interest (ROIs), each one represented in the two hemispheres: anterior (Fp1-AF7-AF3-F7-F5-F3-F1-FT7-FC5 for left, and the corresponding even numbers for right), central (FC3-FC1-T7-C5-C3-C1-CP3-CP1 for left, and the corresponding even numbers for right), and posterior (TP7-CP5-P7-P5-P3-P1-PO7-PO3-O1 for left, and the corresponding even numbers for right). The factors included in the ANOVAs were Valence (positive, negative, neutral), Task (RA, ES), Region (anterior, central, posterior), and Hemisphere (left, right). Violations of sphericity were corrected when necessary by the Greenhouse-Geisser method, and post-hoc tests were corrected by the Bonferroni procedure. Specific time windows for the analyses were selected, based upon visual inspection of the main ERP components.

3. RESULTS

3.1 Skin Conductance Response

The ES task reliably elicited higher levels of arousal, as reflected in standardized SCR (M=1.03, SD= 0.11), compared to the RA task (*M*=.97, SD= 0.11). This difference was significant [$F(1,23)=4.78$, $p<.05$].

3.2. Event-related Potentials

Visual inspection of the waveforms in the RA task (Figure 1) revealed small differences between valences for earlier (EPN) latencies, while at later (LPC) latencies negative valence exhibited a larger amplitude when compared to the other two valences. In the ES task (Figure 2), negative valence displayed substantial EPN, not present for positive valence. The LPC in this task was evident for negative valence.

--Figures 1 & 2 about here--

Statistical analyses, however, did not support a Valence by Task interaction, but the main effects of both independently. EPN was tested in the 230-330 ms time window. ANOVA revealed a significant Valence by Region by Hemisphere interaction [$F(4,92)=4.44$, $p<.01$]. A Valence by Task interaction never appeared (*Fs* between 0.17 and 2.43, $p>.1$). Post-hoc tests revealed main effects of valence in the left posterior and left anterior ROIs [$Fs(2,46)= 6.42$ and 4.63; $p<.005$ and .05, respectively], where differences were always significant between negative and neutral and between negative and positive conditions [$ts(23)= 2.42$ to 3.19, *ps* <.05 to .005]. Positive vs neutral conditions did not reach statistical significance at any ROI ($p>.1$). In this time window, effects of task were seen [$F(1,23)=4.51$, $p<.05$].

The LPC was analyzed in the 600-700 ms time-window, where the largest differences between valences were observed. ANOVA yielded a Valence by Region interaction [$F(4,92)=2.9$, $p<.05$] and, again, an interaction between Valence and Task never emerged (*Fs* between 0.42 and 1.61, $p >.1$). Post-hoc analyses revealed a significant main valence effect on central regions [$F(2,46)=4.67$ $p<.05$], with differences between negative and positive and between negative and neutral valences [*ts*(23)= 2.13 and 2.7, respectively, *ps*<.05]. Positive vs neutral conditions did not reach statistical significance at any ROI (*p*>.1). In this time window, effects of task also appeared [$F(1,23)=12.6$, $p<.05$]. Accordingly, only main effects of valence on EPN and LPC components across tasks are supported, despite the potential differences between tasks suggested by visual inspection. Figure 3 shows these main effects of valence, where EPN and LPC appeared only for negative words.

The significant main effects of task will not be discussed for two reasons. Firstly, the focus of the present work is to test valence effects on word processing across tasks (while controlling arousal). Secondly, due to the nature of the ES task, these effects may be due to a range of factors, such as attention, cognitive load, and arousal, in which this and the RA task notably differ and which are difficult to disentangle with the present design.

--Figure 3 about here--

4. DISCUSSION

The present study aims to explore ERP fluctuations due to word valence independently of arousal, and determine whether these fluctuations vary as a function of the task performed. Arousal in the three valences (positive, negative, neutral) was always equated, while the two tasks explored here were a reading aloud (RA) task and an emotional Stroop (ES) task. Our main finding was a valence effect in both the EPN and the LPC components, and that these modulations appeared blind to the task performed, even if the latter largely differed in the cognitive processes and arousal levels involved. Strikingly, our valence effects were primarily the consequence of negative words displaying the EPN and LPC components, while positive and neutral conditions did not significantly differ from each other.

Accordingly, the EPN component does not seem to be an index of general activation or increased arousal, unspecific of valence. When arousal is equated across valences, including neutral valence, the result is not that emotionally-laden words evoke EPN when compared to neutral words. Instead, EPN is evoked differently by negative and positive valences, as the latter might not show EPN. This result may still be in line with the proposition that this component reflects early automatic stimulus-relevance processing, this relevance plausibly provided by motivational significance (valence meaning) [5,12]. Such effects might be automatic and unconscious, but substantiate early semantic processing of emotional cues. In this line, Bayer & Schacht [12] argue for lexico-semantic access during EPN and, indeed, semantic processing may occur at the latencies at which EPN typically arises [26].

At variance with the few previous reports of word processing in which differences between valences have been reported for the EPN component [12-13], in this study the component was larger, almost exclusively in response to negative words. In previous studies, this pattern was reversed. In Bayer and Schacht [12], a pattern similar to our word stimuli was found for pictures and emotional faces. These authors disregard previous assumptions that such a difference between words and pictures could be due to rather low levels of arousal for words as compared to pictures [27], since their positive words exhibited larger arousal values than the negative ones. Bayer and Schacht attributed this difference between stimulus domains to the fact that, whereas words are cognitively evaluated, pictures and faces hold more imminent information (e.g., about possible dangers). A more realistic assessment of arousal value would thus take place for faces or pictures than for words, the latter therefore yielding inconsistencies between arousal ratings and ERP effects.

In our study, the pattern of results for words was congruent with that normally obtained for emotional expressions or pictures [12], not only for the EPN but also for the LPC component. It remains unclear to what extent this is the consequence of the fact that arousal was equated across the three valences, or that the database used here for arousal scoring [23] is more consistent with realistic assessments than others previously employed. In any event, and in consonance with previous studies using stimuli other than words, we have been able to report a *negativity bias* , i.e., stimuli of negative valence are processed preferentially over positive or neutral stimuli [1], and that this occurs at earlier processing stages.

Regarding the later LPC component, we obtained differential modulations as a function of valence. As mentioned in the introduction, differential valence effects for words on LPC are relatively common in the literature [5,16], although the specific pattern of results may vary depending on the study. Our LPC result was in consonance with the EPN results, that is, only negative words elicited an LPC, while positive and neutral words did not. This is again in consonance with most previous studies using pictures or facial expressions, particularly the latter [12], and a negativity bias is also confirmed, again in line with previous studies using stimuli other than words. Interestingly, while the EPN response to valence is usually reported to be task-independent in word processing, the contrary is the case for the LPC [13], in line with the interpretation of this component as reflecting later high-level deliberative evaluation of the relevance of the stimulus. This is at variance with our results, and may reflect the fact that neither of our two tasks required the participants to make lexical or semantic decisions.

It could be argued that our consistent negativity bias in both the EPN and LPC components might be due to the negative condition provoked by the ES task, in which increased arousal, conflict, interference, and cognitive load concur. However, since the effects of valence reported here never interacted with the task performed, this explanation can be disregarded, as our negativity bias also applies to the emotionally more neutral RA task.

In short, we have found that, across two tasks notably differing in cognitive load and demands, there are significant, specific, task-independent modulations by word valence involving both early (EPN) and late (LPC) brain responses. At variance with most word studies, but in consonance with most studies using pictures or facial expressions, a negativity bias emerged. This could be due to the use of a database to score arousal that might surpass the limitations of the word-normative dictionaries used previously, to the equivalence of arousal values across the three valences, or to both. Further research is necessary to clarify this, using, for example, other databases, or ad-hoc individual scorings of arousal and valence. It is also possible that the use of other tasks, demanding lexical or semantic decisions, could have yielded different results, particularly for the LPC latencies. Further research is also needed in this regard, with strict control of arousal, as used here. Overall, it cannot be held that the EPN response to words reflects the processing of arousal irrespective of the sign of emotionally valenced words. Instead, it seems that both EPN and LPC responses to emotional word processing are largely related, though the former might reflect automatic and the latter more controlled processing stages.

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REFERENCES

[1] L. Carretie. Exogenous (automatic) attention to emotional stimuli: a review, Cognitive, affective & behavioral neuroscience 14 (4) (2014) 1228-58.

[2] J.E. LeDoux, The emotional brain: The mysterious underpinnings of emotional life, Simon & Schuster, New York, 1998.

[3] H.T. Schupp, T. Flaisch, J. Stockburger, & M. Junghöfer, Chapter 2 Emotion and attention: event-related brain potential studies. Progress in Brain Research 156 (2016) 31–51.

[4] J. Kissler, R. Assadollahi, & C. Herbert, Emotional and semantic networks in visual word processing: insights from ERP studies, Progress in Brain Research 156 (2016) 147-183.

[5] F.M.M. Citron, B.S. Weekes, & E.C. Ferstl, Effects of valence and arousal on written word recognition: Time course and ERP correlates, Neuroscience Letters, 533 (2013) 90–95.

[6] P.J. Lang, M.M. Bradley, & B.N. Cuthbert, Emotion, motivation, and anxiety: Brain mechanisms and psychophysiology, Biological Psychiatry 44 (1998) 1248–1263.

[7] D. Sabatinelli, M.M. Bradley, J.R. Fitzsimmons, & P.J. Lang, Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance, NeuroImage 24 (2005) 1265–1270.

[8] J. Kissler, C. Herbert, P. Peyk, & M. Junghöfer, Buzzwords: early cortical responses to emotional words during reading, Psychological Science 18 (6) (2007) 475–80.

[9] F.M.M. Citron, Neural correlates of written emotion word processing: a review of recent electrophysiological and hemodynamic neuroimaging studies, Brain and Language 122 (2012) 211–26.

[10] R.J. Compton, M.T. Banich, A. Mohanty, M.P. Milham, J. Herrington, G.A. Miller, P.E. Scalf, A. Webb & W. Heller, Paying attention to emotion: An fMRI investigation of cognitive and emotional Stroop tasks, Cognitive, Affective, & Behavioral Neuroscience 3 (2) (2003) 81–96.

[11] L Pessoa, Beyond brain regions: Network perspective of cognition-emotion interactions, Behavioral and Brain Sciences 35 (2012) 158–9.

[12] M. Bayer, & A. Schacht, Event-related brain responses to emotional words, pictures, and faces across-domain comparison, Frontiers in Psychology 5 (2014) 1–10.

[13] A. Schacht, & W. Sommer, Time course and task dependence of emotion effects in word processing, Cognitive, Affective & Behavioral Neuroscience 9 (1) (2009) 28–43.

[14] M. Zhang, Y. Ge, C. Kang, T. Guo, & D. Peng, ERP evidence for the contribution of meaning complexity underlying emotional word processing, Journal of Neurolinguistics 45 (2018) 110–118.

[15] K.K. Imbir, T. Spustek, J. Duda, G. Bernatowicz, & J. Zygierewicz, N450 and LPC event-related potential correlates of an Emotional Stroop Task with words differing in valence and emotional origin, Frontiers in Psychology 8 (2017) 1-14.

[16] I.H.A. Franken, L. Gootjes, & J.W. van Strien, Automatic processing of emotional words during an emotional Stroop task, Neuroreport 20 (8) (2009) 776–781.

[17] N. Delaney-Busch, The processing of emotional features in single and primed words, Tifts University, 2013.

[18] N. Delaney-Busch, G. Wilkie, & G.R. Kuperberg, Vivid: How valence and arousal influence word processing under different task demands, Cognitive, Affective & Behavioral Neuroscience 16 (3) (2016),

[19] T. Dresler, K. Mériau, H.R. Heekeren, & E. Van Der Meer, Emotional Stroop task: Effect of word arousal and subject anxiety on emotional interference, Psychological Research 73 (2009) 364–371.

[20] F. Teixeira-Silva, G.B. Prado, L.C.G. Ribeiro, & J.R. Leite, The anxiogenic video-recorded Stroop Color-Word Test: Psychological and physiological alterations and effects of diazepam, Physiology and Behavior 82(2–3) (2004) 215–230.

[21] R.C. Oldfield, The assessment and analysis of handedness: the Edinburgh inventory,

Neuropsychologia 9 (1) (1971) 97–113.

[22] C.D. Spielberger, R.L. Gorsuch, P.R. Lushene, P.R. Vagg, & A.G. Jacobs, Manual for the State-Trait Anxiety Inventory. Manual for the State-Trait Anxiety Inventory, Consulting Psychologists Press, 1983.

[23] J. Redondo, I. Fraga, I. Padrón, & M. Comesaña, The Spanish adaptation of ANEW (affective norms for English words), Behavior Research Methods 39 (3) (2007) 600–605.

[24] J. Espuny, L. Jiménez-Ortega, & M. Martín-Loeches, Untangling valence of emotion effects from arousal on morphosyntactic processing: An event-related brain-potential study (in preparation).

[25] G. Gratton, M.G.H. Coles, & E. Donchin, A new method for off-line removal of ocular artifact: Electroencephalography and clinical Neurophysiology, Electroencephalography and Clinical Neurophysiology 55 (4) (1983) 468–484.

[26] M. Kutas, & K.D. Federmeier, Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP), Annual Review of Psychology, 62 (2011) 621–47.

[27] J.T. Cacioppo, & W.L. Gardner, Emotion, Annual Review of Psychology 50 (1999) 191–214.

FIGURE CAPTIONS

Figure 1: Reading aloud (RA) task. Event-Related Potentials at selected electrodes. A) Early Posterior Negativity (EPN) at PO7 electrode, and B) Late Positive Complex (LPC) at Cz electrode.

Figure 2: Emotional Stroop (ES) task. Event-Related Potentials at selected electrodes. A) Early Posterior Negativity (EPN) at PO7 electrode, and B) Late Positive Complex (LPC) at Cz electrode.

Figure 3: Tasks collapsed. A) and B) 3D maps of differences at 230-330 ms (Early Posterior Negativity, EPN) between negative minus positive (A) and negative minus neutral conditions (B). C) EPN waveforms in response to positive, negative and neutral words. D) and E) 3D maps of differences at 600-700 ms (Late Positive Complex, LPC) between negative minus positive (D) and negative minus neutral conditions (E). F) LPC waveforms in response to positive, negative and neutral words.

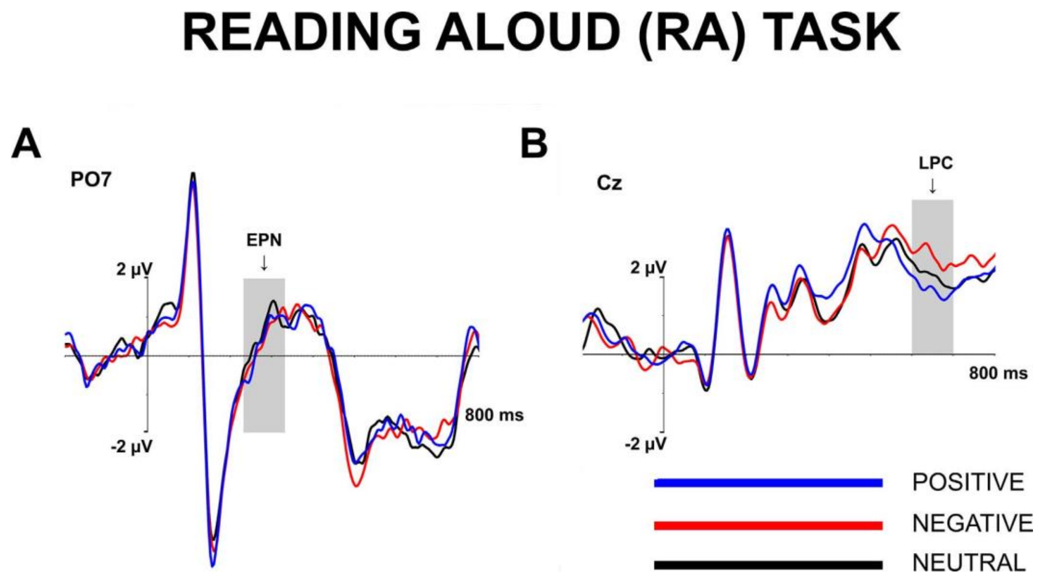
READING ALOUD (RA) TASK
A
PO7
EPN
2 µV
-2 µV
800 ms
B
Cz
LPC
2 µV
-2 µV
800 ms
POSITIVE
NEGATIVE
NEUTRAL

Fig. 1

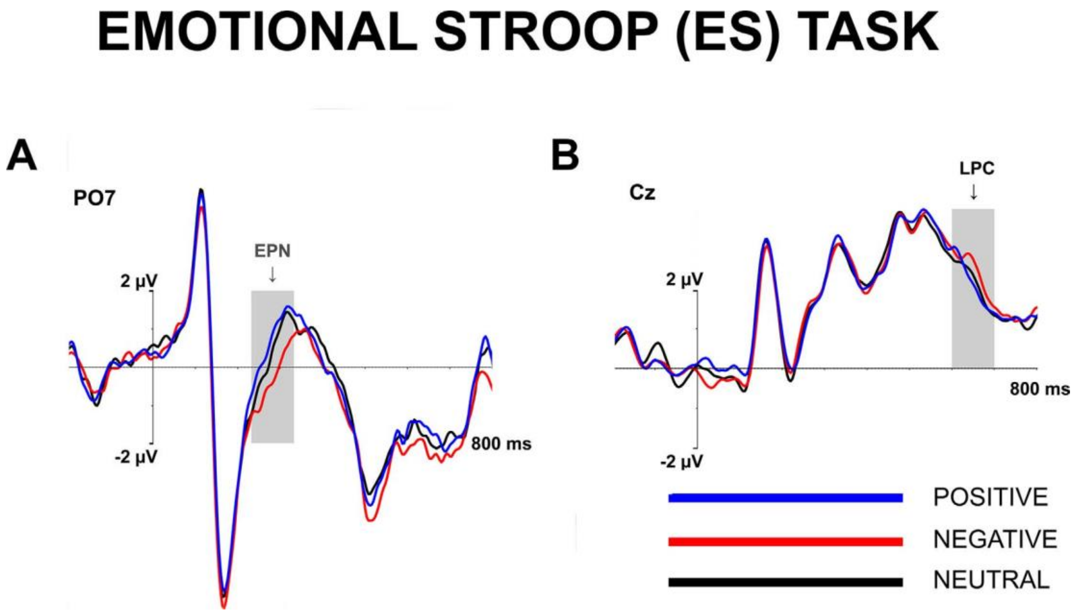
EMOTIONAL STROOP (ES) TASK
A
PO7
EPN
2 µV
-2 µV
800 ms
B
Cz
LPC
2 µV
-2 µV
800 ms
POSITIVE
NEGATIVE
NEUTRAL

Fig. 2

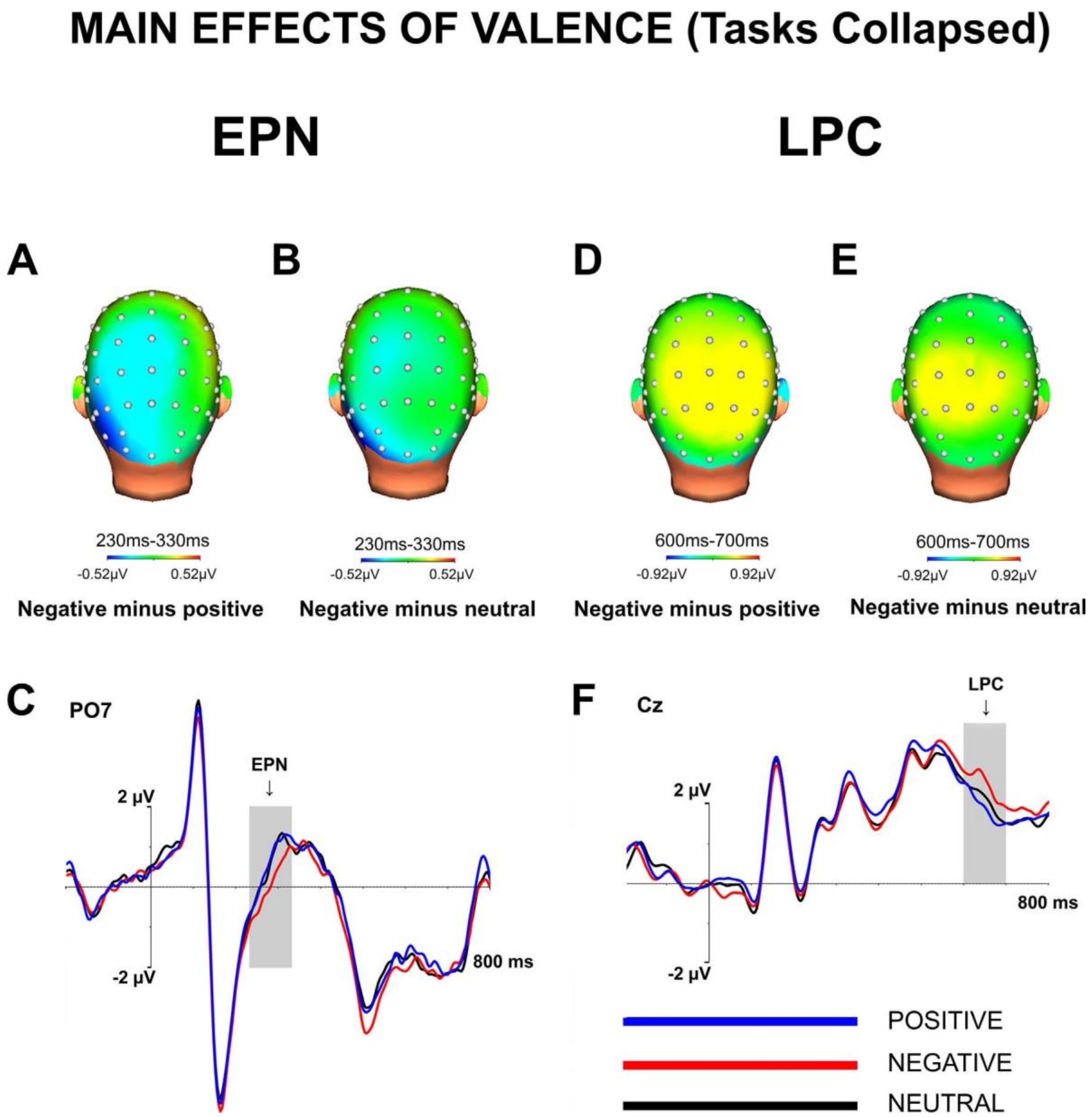
MAIN EFFECTS OF VALENCE (Tasks Collapsed)
EPN
LPC
A
B
D
E
230ms-330ms
-0.52μV 0.52μV
Negative minus positive
230ms-330ms
-0.52μV 0.52μV
Negative minus neutral
600ms-700ms
-0.92μV 0.92μV
Negative minus positive
600ms-700ms
-0.92μV 0.92μV
Negative minus neutral
C
PO7
EPN
2 μV
-2 μV
800 ms
F
Cz
LPC
2 μV
-2 μV
800 ms
POSITIVE
NEGATIVE
NEUTRAL

Fig. 3