Hemispheric asymmetries in recognition memory for negative and neutral words

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ABSTRACT

Federmeier and Benjamin (2005) have suggested that semantic encoding for verbal information in the right hemisphere can be more effective when memory demands are higher. However, other studies (Kanske & Kotz, 2007) also suggest that visual word recognition differ in function of emotional valence. In this context, the present study was designed to evaluate the effects of retention level upon recognition memory processes for negative and neutral words. Sample consisted of 15 right-handed undergraduate portuguese students with normal or corrected to normal vision. Portuguese concrete negative and neutral words were selected in accordance to known linguistic capabilities of the right hemisphere. The participants were submitted to a visual half-field word presentation using a continuous recognition memory paradigm. Eye movements were continuously monitored with a Tobii T60 eye-tracker that showed no significant differences in fixations to negative and neutral words. Reaction times in word recognition suggest an overall advantage of negative words in comparison to the neutral words. Further analysis showed faster responses for negative words than for neutral words when were recognised at longer retention intervals for left-hemisphere encoding. Electrophysiological data through event related potentials revealed larger P2 amplitude over centro-posterior electrode sites for words studied in the left hemifield suggesting a priming effect for right-hemisphere encoding. Overall data suggest different hemispheric memory strategies for the semantic encoding of negative and neutral words.

1. INTRODUCTION

An important research area in neuroscience is the study of information processing asymmetries between cerebral hemispheres. Research on hemispheric specialization revealed that the left hemisphere (LH) is considered as a dominant, verbal, analytical and more intelligent, whereas the right hemisphere (RH) is considered as visuospatial, holistic and more creative (Harrington, 1987). The LH is the dominant hemisphere for language processing, although recent language research studies suggests that RH can also play an important role in language processing (Mashal, Faust, Hendler & Beeman, 2007).

Findings from studies based on lexical decision paradigms for words and non-words, have also verified that words are processed more effectively when they are presented directly to LH than to RH (see Hellige, 1993 for a review). These conclusions are drawn from paradigms with visual half-field presentation, in which word stimuli that have been presented in the right visual field (RVF) were identified more accurately than those presented in the left visual field (LVF). Eviatar, Ibrahim, and Ganayim (2004), stated that this LH advantage for word processing in divided field experiments was a consequence of reading direction in Western languages. More specifically, in Western languages subjects read form left to right which can create artificial advantages for RVF/LH in detrimental of LVF/RH.

To study this phenomenon, several modifications were made to lateralised word experiments. With vertically presented words the results are contradictory, for example, Young and Ellis (1985), observed an advantage for LH in a vertical word presentation task, whereas Babkoff, Faust and Washer (1997); Lavidor, Babkoff and Faust (2001) found a decreased advantage of the LH by the RH for vertical word presentation when compared to a common horizontal presentation task. Recent reviews indicated that vertical word presentation does not reflect the natural reading process. In agreement with Jordan, Redwood and Patching (2003), to evaluate reading strategies between cerebral hemispheres and to ensure the ecological validity of these results, lateralised word experiments must preserve the horizontal presentation of the words.

The most widely accepted interpretation for this RVF/LH advantage in word processing is based on the anatomy of the human visual system. Due to the structure of the visual system, stimuli presented in the RVF are directly projected to the LH (dominant hemisphere for language processes), while stimuli presented in the LVF are projected to the RH. Consequently, word stimuli presented in the RVF takes advantage because this data is assessed primarily by the LH language processes, whereas, to reach this hemisphere, words presented in the LVF have to cross a longer path (Upton, Hodgson, Plant, Wise & Leff, 2003).

Regarding the study of hemispheric specialisation in memory functioning, Federmeier and Benjamin (2005) have suggested that semantic encoding of verbal information in the RH can be more effective when memory demands are higher. These conclusions are drawn from a visual word recognition task with visual half-field design. Memory demands were manipulated according to the interval between encoding and retrieval that varied at nine levels (1, 2, 3, 5, 7, 10, 20, 30 and 50 items). The results showed a general LH advantage, nevertheless, for a longer retention interval between encoding and retrieval, asymmetries were reduced and the LH advantage was attenuated.

One possible explanation is related to LH linguistic capabilities, which rapidly change verbal information into integrated word representations. In contrast, the RH semantic encoding for verbal information is more superficial, producing less semantic interference and resulting in a more effective storage strategy when memory demands are higher (Federmeier et al. 2005). In addition, electrophysiological evidence of RH memory capabilities relies on early ERP components. Evans and Federmeier (2007) studied the P2 repetition effect, where increases in P2 amplitude can be associated to perceptual matching processes. This early component usually starts at approximately 200 ms and is typically observed over frontal and temporo-parietal regions. Data showed an increase in P2 amplitude for correctly recognised words presented in the LVF/RH, revealing a priming effect for RH encoded words, which can indicate higher verbal memory capabilities in this hemisphere. Indeed, Metcalfe, Funnell and Gazzaniga (1995) have suggested that verbal information is encoded in a more interpretative or inferential way in the LH, while for RH, information is encoded as more exact and in a veridical way. The LH might incorporate verbal information as an interpreted representation, whereas the RH might store information about the individual characteristics of the stimuli.

However, there are other factors that can contribute to memory functioning for verbal information. In agreement with Scott, O'Donnell, Leuthold and Sereno (2009) high arousal stimuli are recognised more accurately due to their environmental significance. Word stimuli are considered as less arousing than pictures, however emotional words, regardless of polarity, can elicit higher arousal levels when comparing to neutral word stimuli. This idea is based on assumptions of the motivational systems theory (Lang, Bradley, & Cuthbert, 1997). According to this theory, emotion triggers two independent motivational systems (appetitive vs. aversive). The appetitive system is opposed to the aversive system and are activated by emotion-evoking stimuli, being the appetitive triggered by positive relevant stimuli, whereas the aversive by negative relevant stimuli. According to this perspective is expected that emotional stimuli (positive and negative) have memory advantages over neutral stimuli (Nagae & Moscovitch, 2002).

Some previous studies have demonstrated that performance on visual word processing is dependent of emotional properties of the words. For example, Scott et al. (2009) found that emotional words, being positive or negative, are faster identified than neutral words. Kousta, Vinson and Vigliocco (2009) also claimed that negative and positive words are processed faster and more accurately than neutral or non-words, suggesting that emotional valence have a priming effect in the processing of verbal stimuli.

As regards to the hemispheric asymmetries, research in emotion processing suggests two different theoretical models, the right-hemisphere model and the valence-arousal model. The RH model suggest a right hemisphere involvement for both negative and positive processing (Cicero et al., 1999), whereas the valence-arousal model proposes that the LH is more concerned to the processing positive emotions and the RH to negative emotions (Davidson, 2003). However, previous data of Strauss (1983); Eviatar, Meen and Zaidel (1990) don not support the RH model neither the valence-arousal model.

More recently, Kanske and Kotz (2007) used a lexical decision task based on a visual half-field design with abstract and concrete words which were positive, negative and neutral in emotional valence. Data were analysed in terms of behavioral responses and ERP, revealing faster responses for positive and negative when compared to neutral words. Electrophysiology showed early ERP effects of emotion on word processing which can reflect an automatic emotional word processing. Also, late ERP effects were observed in emotional word processing (N400 and Late Positive Complex – LPC). The N400 is associated with semantic processing, in particular, the integration of new semantic information and is typically observed over centro-parietal areas (Kutas & Federemeier, 2000). On the other hand, the LPC is thought to reflect memory strength and successful recognition especially over the left temporo-parietal region (Evans et al. 2007).

A separate literature has found enhanced memory for negative stimuli. Maratos, Allan and Rugg (2000) and Windmann and Kutas (2001) have found higher recognition performance for negative words but negative valence increased a positive-going shift only in early memory components. Overall, these findings indicate that word emotionality can modulate early ERP components in recognition memory tasks and further suggest an enhanced memory functioning for emotional words.

Ali and Cimino (1997) have also studied the hemispheric specialisation for emotional words and carried out a visual half-field task with positive, negative and neutral words and non-words assessed in a perception, free recall and a recognition memory tasks. The authors found that only recognition memory data provided support for valence-arousal model of emotion processing. Later, Nagae et al. (2002) using free recall and a perceptual identification task with positive, negative and non-emotional words have found that recall of positive and negative words was better than for non-emotional words in both hemispheres. Also, the recall of non-emotional words was better for the LH than for the RH. As for perceptual identification task, results have suggested that word identification was higher for LH in both word conditions. Mneimne, Powers, Walton, Kosson, Fonda & Simonetti (2010) tested immediate recall and recognition memory with emotional words. The authors found that LH encoded words were better recalled and recognised than for RH. Overall, their findings only partially confirmed the RH and the valence-arousal models, suggesting a new integrated model of emotion processing within explicit memory context.

Our intent was to study prior assumptions of Federmeier et al. (2005) regarding the hemispheric asymmetry in recognition memory with emotional words. The literature on hemispheric specialisation for emotion processing suggests that emotional valence can play a significant role in word processing and recognition. Therefore, our purpose was to assess if possible effects of memory demands on hemispheric memory strategies can be modulated by emotional valence of words. If emotional valence enhances word recognition we would expect an interaction of emotional valence and memory demands in word recognition performance. However, given previous evidence of RH dominance for emotional processing, we would expect an interaction of emotional valence and visual field of presentation in word recognition performance. We would expect also an effect of word emotionality on early memory components. Thus, we hypothesized that recognition performance would be increased for negative than for neutral words when memory demands are higher and for RH encoding as well. Furthermore, a positive-going shift would be expected around 200 ms. for negative word encoding.

2. METHOD

2.1 Participants

Fifteen undergraduate Portuguese students (8 male and 7 female) with a mean age of 22.47 years (SD = 2.07) and with more than 14 years of formal education. The inclusion criteria were as follows: (1) being native Portuguese speakers; (2) having more than 12 years of formal education; (3) being right-handed according to Annett Handedness Inventory (Briggs & Nebes, 1975); (4) having normal or corrected to normal vision; and (5) being without neurological or psychiatric disorders.

2.2 Materials

A total of 108 Portuguese concrete nouns were collected from Garcia-Marques (2003), 54 negative and 54 neutral words with four to six letters and high frequency of use in the Portuguese lexicon.

The experiment was based on a continuous recognition memory paradigm (Shepard & Teghstoonian, 1961), using divided visual field technique with word presentation in the left visual field (LVF) or right visual field (RVF) in the study phase and tested at the centre of the screen. In the classic continuous recognition memory paradigm, word stimuli are presented twice on each experiment, where subjects have to note the first occurrence of a word and recognize each stimulus on its second presentation.

According to this within-subjects design, 36 negative and 36 neutral words were presented as study words in the study phase and the remaining 18 negative and 18 neutral words as test or interference words presented only in the test phase combined with previous study words.

Memory demands were manipulated through the retention interval between study and test phases, where lags of 1 (immediate repetition), 2 and 3 words were considered as shorter retention levels, lags of 5, 7 and 10 as moderate retention, lags of 20, 30 and 50 words as longer retention levels.

2.3 Procedure

The participants were seated at a distance of 60 cm of the eyetracking screen and were connected to electrodes for EEG recording. The experiment was designed using SuperLab software (v.1.0.2; Cedrus Corporation) installed on a P-IV 3.4 GHz CPU. The visual half-field presentation started with a 5 min preliminary task practice phase with proper nouns, followed by the experimental task where subjects were instructed to maintain visual contact with a central fixation dot during the experiment and to recognise words with button press (YES or NO) only when words appeared in the centre of the screen. All words were presented in 38 point Arial font with black capital letters in a white background with 1024x768 pixels of screen resolution. Study words were presented during 200 ms with an inter-stimulus interval of 2300 ms, preceded by a central fixation dot during 500 ms and lateralised between 2.8º and 4.3º from the centre of the screen. Test words remained on the centre of the screen until button press.

Because words were presented either at right or left of a central dot, word fixations were assessed with an eye tracking Tobii T60 system. The trials in which were observed word fixations were further removed from behavioural analyses and ERP averaging. EEG recording was also carried out during the experiment for 19 Ag/AgCl active electrodes (BrainAmp Standard from Brain Products, GmbH) in accordance with the 10-20 international system with left mastoid reference and a sampling rate of 500Hz. Data was band pass filtered (0.05 - 50Hz) and signals above 75 µV were automatically rejected. ERP averages were calculated for each participant in a time window from -100 to 1000 ms at word onset for second occurrence (test phase). The P2 component was estimated between 210 and 300 ms time window and was analysed only for correctly recognised studied words in the following conditions: negative and neutral words encoded in the RVF/LH and LVF/RH.

3. RESULTS AND DISCUSSION

3.1. Fixations during visual half-field word presentation

A Repeated Measures ANOVA revealed no significant differences in fixations to negative (M = 2.33; DP = 2.09) and neutral words (M = 2.27; DP = 2.31) were observed ($F(1, 14) = 0.025$; MSe = 1.319; $p > 0.05$ – see Table 1). Word fixations at study were observed in thirteen participants and approximately on 6% of the trials.

Table 1. *Descriptive statistics for fixations during visual half-field word presentation*

	Minimum	Maximum	Mean	Std. Deviation
Negative	0	7.00	2.33	2.09
Neutral	0	6.00	2.27	2.31

3.2. Discrimination analysis

Discrimination index (d') in word recognition was estimated by the difference between standardized distributions for false alarms and hit rates in word recognition.

A Repeated Measures ANOVA with three within-subject variables was performed for emotional valence (negative and neutral words), visual field (RVF, LVF) and retention level (Short, Moderate and Long). The ANOVA showed an interaction between visual field of presentation and word emotionality ($F(8, 14) = 5.630$; MSe = 0.38; $p < 0.05$). Interaction between factors was further explored with simple effects analysis which showed a significant effect of emotionality in the RVF/LH ($F(8, 14) = 9.47$; MSe = 0.10 $p < 0.05$ – see Figure 1), indicating higher accuracy for negative words.

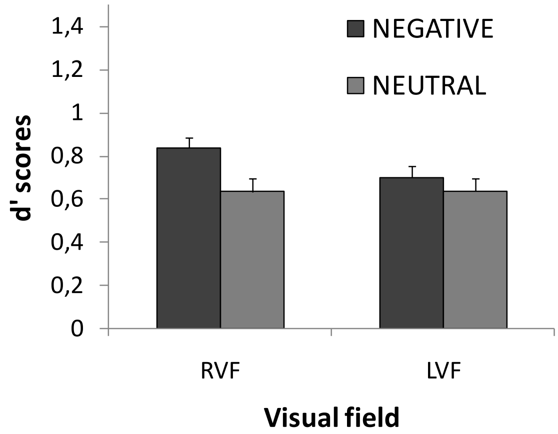

Figure 1. *Discrimination analysis in word recognition*

Contrary to our initial hypothesis, negative words encoded in LH were better recognized than in RH. With a lexical decision paradigm, Kanske et al. (2007) have demonstrated that positive and negative words were better identified than neutral words, but no interaction between emotionality and visual field was found. Our data are in partial agreement with Kanske et al. (2007) and does not confirm the lateralization theories in emotional processing which suggest a RH involvement in emotional processing (Cicero et al., 1999; Davidson, 2003).

The LH advantage may also be related to specific aspects of word reading, as claimed before by Eviatar et al. (2004). In their view, lateralised word presentation tasks can produce artificial results favouring the LH for words presented in RVF. In sum, the results from recognition accuracy are consistent with Mneimne et al.'s (2010) findings suggesting that neural system involved in processing of verbal emotional stimuli can be more complex than the assumptions suggested by the RH or valence-arousal models.

3.3. Reaction time analysis

Reaction times (RTs) were analysed only for correct responses in word recognition. To assess RTs in word recognition, data were also submitted to Repeated Measures ANOVA with the same three within-subjects factors (emotional valence, visual field and retention level). Data revealed a three-way interaction effect ($F(2, 14) = 7.145$; $MSe = 25188.94$; $p < 0.01$). This three-way interaction was further decomposed by testing simple interaction effects of visual field X retention for negative and neutral words.

In order to test interaction between visual field and retention for each emotion category, simple interaction effects revealed that interaction between visual field and retention level was statistically significant for both negative ($F(2, 14) = 5.20$; $MSe = 29416.7$; $p < 0.05$) and neutral words ($F(2, 14) = 6.56$; $MSe = 23369.7$; $p < 0.05$). A simple main effect of visual field was observed for negative words recognised at shorter retention levels ($F(1, 14) = 6.37$; $MSe = 35093.8$; $p < 0.05$), indicating faster responses to LVF/RH encoded words when compared to RVF/LH. Also, a simple main effect of visual field was observed for neutral words recognised at longer retention levels ($F(1, 14) = 11.78$; $MSe = 33559.1$; $p < 0.01$), that suggested faster responses for LVF/RH encoded words when compared to RVF/LH (see Figure 2).

As far as psychomotor processing speed is concerned, the comparison between RH and LH encoding revealed a RH advantage for negative words at shorter retention levels, whereas neutral words were faster recognised for RH encoding at a longer retention interval.

However, accordingly to RH or valence-arousal models it was expected that this effect was clear for negative words at all retention intervals. One possible explanation for this inconsistency between our data and previous studies of Maratos et al. (2000) and Windmann et al. (2001) can be explained by the stage of processing in which words were recognised.

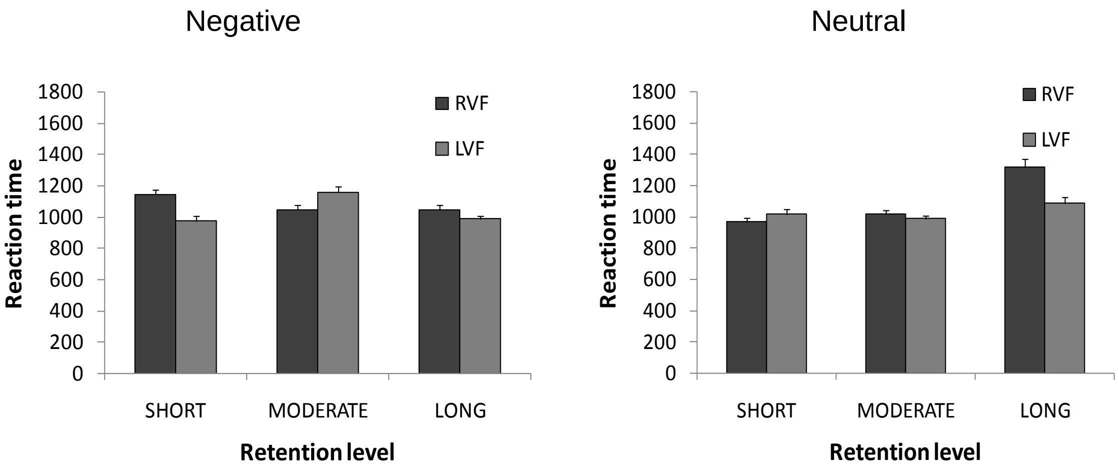

Figure 2. *Reaction time analysis for negative (left figure) and neutral (right figure) words.*

Root, Wong and Kinsbourne (2006) have suggested that stage of processing can affect hemispheric strategies in emotional processing. According to these authors, RH models provide consistent support at an early stage of perceptual identification, whereas the valence-arousal model at response preparation. In fact, it seems that the retention level in which words were recognised may have affected recognition performance of emotional stimuli.

In agreement with Metcalfe et al. (1995), memory strategies differ between cerebral hemispheres and can be affected by memory demands. Federmeier et al. (2005) have suggested that there is deterioration in memory performance in the LH and RH with the increase of memory requirements, and that this effect can be more exacerbated in the LH than in the RH, mainly because the RH might focus on the visual properties of the input stimuli, rather than on their semantic nature. This previous findings can help to explain our results. Although the present study was designed with concrete emotional words and non-emotional words, asymmetries between LH and RH were clear for neutral words tested at longer retention which are in agreement with Root et al. (2006) but also with Federmeier et al. (2005).

Even though our results are contrary to some of previous studies, RT data is partially consistent with Kanske et al. (2007) and Mneimne et al. (2010), suggesting a priming effect for emotional stimuli. According to Scott et al. (2009) emotional stimuli can be better recognised due to their environmental significance. This assumption is relative to the motivational systems theory of Lang et al. (1997) which posit a processing advantage of negative emotional stimuli over neutral stimuli.

3.4. P2

Electrophysiological data was analysed only for correctly recognised test words. Data was analysed not considering the retention level between study and test in order to have sufficient trials for ERP averaging and provide stable P2 components. Thus, a Repeated Measures ANOVA with two within-subjects factors (emotional valence and visual field) was performed also for electrophysiological data with the P2 component. Results showed an increased P2 mainly over the Pz electrode site for words encoded at LVF/RH in comparison to RVF/LH encoding ($F(1, 14) = 7.582$; $MSe = 1.864$; $p < 0.05$ – see Figure 3 and Figure 4).

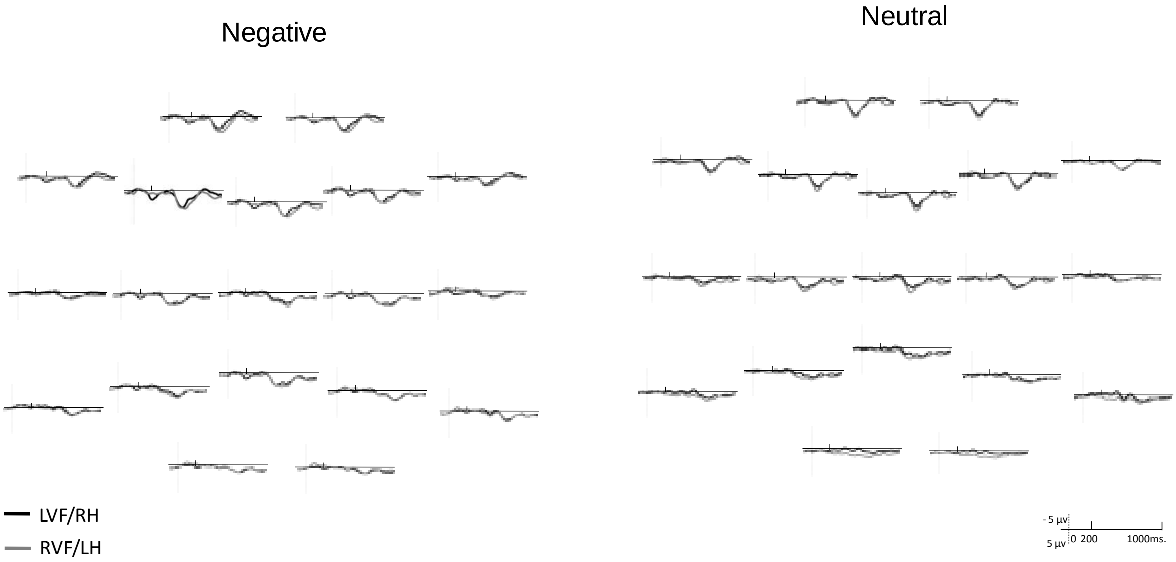

Figure 3. *Grand average ERP for correctly identified negative (left) and neutral (right) words. Negative is plotted up.*

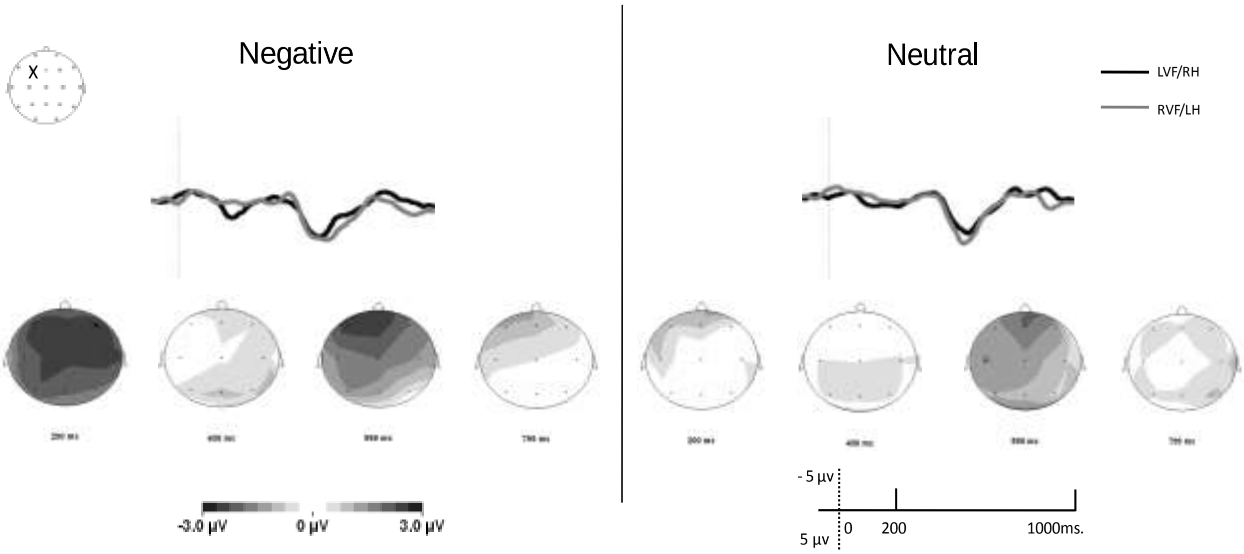

Figure 4. *Grand average ERP for correctly identified negative (left) and neutral (right) words and the topographic maps for the distribution of visual field effects (difference waves between RVF/LH and LVF/RH encoded words).*

Electrophysiological data through event related potentials revealed larger P2 amplitude over centro-posterior electrode sites for words studied in the left hemifield suggesting a priming effect for RH encoding of words. Although our data are similar to those of Evans et al. (2007), which reported P2 repetition effects for RH, this does not confirm our study hypothesis.

Within memory paradigms, increases in the P2 component for words encoded at RH can reveal higher verbal memory capabilities in the RH when compared to LH which, in turn, are consistent with our RT data for non-emotional words and can support previous findings from Federemeier et al. (2005) and Metcalfe et al. (1995). Nevertheless, our results have failed to replicate valence effects on P2 reported in the literature on emotion processing.

Despite a RH advantage was not observed for accuracy to negative words, the results obtained for RT and electrophysiology provide evidence supporting a RH advantage for visual word recognition. On the other hand, we did not find support for lateralization models of emotion. This lack of support can be due to methodological differences between our study and some previous studies. Indeed, we have assessed hemispheric specialisation of emotional stimuli with horizontal word presentation based on a continuous recognition memory paradigm which was different from other previous studies reported in the literature.

Another concern is related to word stimuli used. In our study valence effects were based only on negative versus neutral words while Maratos et al. (2000) and Windmann et al. (2001) have studied valence with positive, negative and neutral words. This can be considered as a limitation, since without positive words our results can hardly confirm the valence-arousal model for emotional processing.

4. CONCLUSIONS

In summary, our results can suggest a priming effect for emotional stimuli that can be explained by their environmental significance as previously stated by motivational systems theory. This effect was clearer for the LH which contradicts previous predictions of RH model for emotional processing and can suggest a more complex model to describe the neural system involved in processing of verbal emotional stimuli. Recognition asymmetries between RH and LH were dependent of word emotionality and memory demands as well. These data can be explained by the stage of processing in which words were recognised. In fact, we have observed a RH advantage for negative words at shorter retention levels which are in agreement with RH models providing evidence for RH superiority at an early stage of perceptual identification. Even though our data did not confirm the RH model for emotional processing, the positive going electrical potential at 200 ms. after stimuli onset for RH encoding suggest higher verbal memory capacity in this hemisphere. However, taking into account the mixed findings between our study and previous literature, we consider that further data are needed in order to elucidate the differences across studies regarding the effects of emotional valence upon verbal memory performance.

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