Neuroscience Letters 714 (2020) 134538

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research article

Processing gender agreement errors in pleasant and unpleasant words: An ERP study at the sentence level

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ARTICLE INFO

Keywords:
Emotional words
Event-related potentials
Gender agreement
LAN
P600

ABSTRACT

In this study we examine the extent to which aspects such as the emotionality coded in words may interfere with the processing of gender agreement errors in a sentence grammaticality judgement task. We follow the methodological pattern of our previous experiments, using consistently the same kind of structure and task (gender agreement) and only emotional (pleasant vs unpleasant) words, in an attempt to clarify whether neural correlates and performance show similar patterns in positive and negative words. We found an emotional effect in the N400 time window for unpleasant adjectives as well as the classic grammaticality effects in the left anterior negativity (LAN) and the P600 components. Overall, our results confirm those of our previous studies in that the LAN and the P600 grammaticality effects are not influenced by the emotional valence of moderately arousing pleasant and unpleasant words, showing that during sentence reading morphosyntactic error detection seems to be encapsulated.

1. Introduction

In visual word recognition, it has been broadly established that emotional words show differences in comparison to neutral words. Behavioural studies have shown that emotional content facilitates lexical decision and recall, and that pleasant and unpleasant words may also behave differently from each other. For instance, positive words may be recognized more accurately than negative and neutral ones, and negative words give rise to greater interference in Stroop tasks (see [6] for a review of all these findings). Electrophysiologically, emotional words have shown effects as rapidly as in the 80–120 ms time range [3,10,24,26], although as regards early effects, the most consistent finding points to the 200–300 ms window, the so-called Early Posterior Negativity [5,42]. Medium and late effects have emerged in latencies around 400 ms (the N400 component [23,32]) and 500–800 ms (the Late Positive Complex (LPC) or Late Posterior Positivity (LPP) [5,12,30]), both with a parieto-central topographic distribution. In the time course registered by event-related potentials (ERPs), early emotional effects are interpreted in terms of attention capture and maintenance, while late effects are associated to strategic higher-level control [5] and evaluative processing [6] (for a recent review on neural correlates of emotional words, see [25]).

In psycholinguistics, a classic line of research involves studying to what extent syntax and semantics interact. Thus, a number of lexico-semantic variables, such as animacy, concreteness or frequency have been shown to affect syntactic processing (e.g., [9,39]). However, only recently has it become interesting to study whether a 'genuinely psychological' dimension, namely emotionality, can actually affect 'genuinely syntactic' processes. Note that, unlike emotion words (e.g., *happiness*, *fear*), emotion-laden words (e.g., *death*, *smile*, *scream*) add *affect* (in terms of valence/pleasantness and arousal/intensity) to the matrix of their other lexico-semantic variables (e.g., frequency, age of acquisition, imageability, etc.), that is, their emotionality is still a distinct property separate from these [6,10]. To what extent emotional valence is not only an idiosyncratic semantic feature, but also a part of the lexical representation of words is still a matter under study [25,38].

In this line, Fraga, Piñeiro, Acuña-Fariña, Redondo & García-Orza [16] showed that high arousal positive and negative words did induce changes in syntactic preferences by Spanish speakers. Using a sentence completion task, these authors demonstrated that, all other things being equal in grammatical terms, participants tended to produce a sentence in which the subject of a relative clause (RC) with two possible antecedents was the one with an emotional value. Thus, for instance, in "Someone shot *the murderer* (a negative word) of the servant (a neutral word) who…", participants mostly completed the sentence by referring to the first noun-phrase (NP1, *the murderer*), while in "Someone shot the

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https://doi.org/10.1016/j.neulet.2019.134538
Received 18 July 2019; Received in revised form 13 September 2019; Accepted 7 October 2019
Available online 15 October 2019

servant of *the artist* (a positive word) who…", they completed the sentence by referring to the noun in the second position (NP2, *the artist*). There is reason to believe that in sentence production tasks like the one in these studies active conceptualisations are probably more likely to interact with lexico-semantic variables than in comprehension tasks. As a matter of fact, García-Orza et al. [22] only obtained a moderate and early-vanishing effect of emotionality on RC disambiguation in a self-paced reading task. As suggested by these authors, models of sentence processing, such as Construal [18] or constraint satisfaction models (e.g. [2,29,33,43],), could explain these effects of emotionality on sentence disambiguation, yet based on different mechanisms. However, should this effect emerge in the time course of lower-level comprehension processes that rely more on structural information [17], such as the establishment of gender or number agreement (e.g., *they dance*, *s/he dances*) in self-paced reading tasks, then the modularity hypothesis (i.e, the view that grammar is separate from general cognitive mechanisms and principles) would be seriously compromised.

Therefore, the aim of the present study is to analyze whether at some moment along the time course of reading sentences containing NPs with pleasant and unpleasant words, emotionality influences the detection of morpho-syntactic errors, since the available evidence is still scarce and has provided contradictory results. Both gender and number violations have been widely studied with the ERP technique. Results show that there are two main components which are typically elicited by these syntactic anomalies: The Left Anterior Negativity (LAN) and the P600 component. The former appears between 300–500 ms after stimulus onset in left-anterior positions although it has also been registered in fronto-central electrodes [1,7,35]. It is related to the early detection of morpho-syntactic violations and to some aspects of working memory processes [20,35]. The later component is a positive shift starting around 500 ms after stimulus onset over centro-parietal positions [19,35] and it is usually interpreted as a late stage of reanalysis that reflects the cost of repair and revision of mismatches and/or integration processes caused by different sources of information [35].

The first studies aimed at specifically studying the effects of emotionality on the processing of morpho-syntactic violations were those by Martín-Loeches et al. [34] and Hinojosa et al. [24]. In both studies, an interaction of emotionality and grammaticality was found in the time window of 300–450 ms (LAN effects), although with different results for negative words. Thus, on the one hand, the first authors reported an augmented LAN in phrases like *La chica*$_{sg}$ *feas*$_{pl}$ *baila* [The ugly$_{pl}$ girl$_{sg}$ dances], while the second authors found a decreased LAN in unpleasant words versus neutral words embedded in NPs (e.g., *El camarero*$_{masc}$ *furiosa*$_{fem}$ [The furious$_{fem}$ waiter$_{masc}$]). More recently, Jiménez-Ortega et al. [27] used subliminal emotional adjectives inserted within neutral mismatch sentences and also reported a lack of LAN in neutral words preceded by unpleasant ones. On the other hand, Martín-Loeches et al.'s study [34] reported differences in word valence, since unlike unpleasant words, pleasant ones evoked a decreased LAN in mismatch sentences (as in *La hermana*$_{sg}$ *queridas*$_{pl}$ *acude* [The dear$_{pl}$ sister$_{sg}$ attends]).

Contrary to these results of an interaction between grammaticality and emotionality of one kind or another, in a series of experiments in our lab, Díaz-Lago et al. [10] and Fraga et al. [14] found that ungrammaticality (gender agreement errors) resulted in LAN and P600 brain waves which were insensitive to any emotional manipulation. These authors used longer, more natural sentences (e.g., *Tania tiró el pescado*$_{[masc]}$ *podrida*$_{[fem]}$ *que estaba en la nevera* [Tania threw away the rotten$_{[fem]}$ fish$_{[masc]}$ that was in the fridge]), and the same items across the three experiments, thus facilitating the comparability of the results. Interestingly, Díaz-Lago et al. [10] obtained higher amplitudes for positive words in both the N100 component and the LPC component. However, these effects were not replicated in Fraga et al 2017 [14]. It is possible that differences in materials (as for instance, the size of the linguistic unit to be processed, that is, NPs, short or long sentences, etc.), procedures, and tasks (gender/number), as well as the composition of the experimental lists across the abovementioned studies may explain at least some of the different results found. We should keep in mind that Martín-Loeches et al. [34] used a number agreement manipulation with short sentences containing either positive, negative or neutral adjectives. Hinojosa et al. [24] used a gender instead of number agreement task and NPs instead of clauses. Díaz-Lago et al. [10] used pleasant vs neutral words and Fraga et al. [14] used unpleasant vs neutral (Experiment 1) and pleasant vs neutral vs unpleasant (Experiment 2) words inserted in long sentences. Table 1 summarizes the characteristics of all these studies and their main results.

In the present study, we seek to analyze the time course of processing gender agreement errors in the presence of positive and negative adjectives embedded in the same sentences as the ones used in our previous experiments. Our main goals are: 1) to check which early, medium and late ERP emotionality and grammaticality effects are consistent and remain across experiments, regardless of the item list composition, 2) to confirm the lack of an interaction between grammaticality and emotionality in the LAN/N400 and P600 time windows when emotional words are inserted in long sentences, and 3) to test whether positive and negative words behave differently or not (as they did in Martín-Loeches et al. [34] and Hinojosa et al. [24]). Based on our previous results, we predict a) no early effects for either pleasant or unpleasant words, b) a lack of interaction between grammaticality and emotionality along the time course, and c) higher amplitudes in LPC for pleasant adjectives.

2. Materials and methods

2.1. Participants

Twenty-six Spanish native speakers from the University of Santiago de Compostela (22 females) between 19 and 24 years of age (Mean age = 21.12, *SD* = 0.99) participated in the study. All volunteers were right-handed according to the adaptation of the Edinburgh Handedness Inventory [37] (ranging from 10 to 50, being 10 = always right and 50 = always left; *M* = 16). All participants reported normal or corrected-to normal vision and no history of neurological disorders. They gave written informed consent to participate in the study and they were rewarded with course credits.

2.2. Materials

We used 200 experimental sentences in which a direct object NP contained an adjective in the following frame: "Subject + Verb + Direct Object + Others". The modifying adjective was the critical word. We manipulated the emotionality of the critical adjective and the gender agreement of the adjective with the head noun. Fifty neutral nouns were chosen and modified by 50 emotional adjectives (25 unpleasant and 25 pleasant). Nouns and adjectives in the direct object were selected from several Spanish emotional databases: the Spanish adaptation of ANEW [40], B-Pal [8] and the database for words denoting animals, people and objects [11].[1]The nouns had intermediate levels of valence (*M* = 5.19) and arousal (*M* = 4.87). The adjectives embedded in the unpleasant sentences had low valence scores (*M* = 2.40) and moderate arousal scores (*M* = 6.14) and the adjectives in the pleasant sentences had high valence scores (*M* = 7.60) and similar moderate arousal scores to those in the unpleasant ones

[1] The valence and arousal data for the names and adjectives were extracted from several Spanish emotional databases. In all of them, following the norms used in the original Bradley and Lang report [4] a pictorial scale - SAM of 1-9 was used to rate the valence and arousal dimensions, being 1-unpleasant and 9-pleasant for the variable valence, and 1-calm and 9-very aroused or excited, for arousal.

Table 1
Schematic summary of principal ERPs studies mentioned in this article, with information regarding linguistic unit, task, materials and the main ERPs results. E: Emotionality effects; G: Grammaticality effects; GxE Interaction (LAN/N400); (a): increased LAN in unpleasant words and decreased LAN in pleasant words; b): reduced LAN in unpleasant words.

Study	Linguistic Unit	Task	Word valence (valence and arousal values in parentheses)	N100 EPN	LAN / N400			P600	LPC
				E	G	E	G x E	G	E
Martín-Loeches et al. (2012, Exp.1)	Short sentences [det/noun/**adj**/verb]	Number agreement task	Pleasant (7.2; 3.2), Unpleasant (3.0; 3.3), Neutral (5.1; 2.3)	x	✓	x	✓ [a]	✓	x
Hinojosa et al. (2014)	NPs [det/noun/**adj**]	Gender agreement task	Unpleasant (2.1; 6.9), Neutral (5.2; 4.1)	x	✓	x	✓ [b]	✓	x
Díaz-Lago et al. (2015)	Long sentences [det/noun/direct obj (det/noun/**adj**)/…]	Gender agreement task	Pleasant (7.6; 5.7), Neutral (5,1; 4.8)	✓	✓	x	x	✓	✓
Fraga et al. (2017, Exp.1)	Long sentences [det/noun/direct obj (det/noun/**adj**)/…]	Gender agreement task	Unpleasant (2.4; 6.1), Neutral (4.9; 4.8)	x	✓	x	x	✓	x
Fraga et al. (2017, Exp.2)	Long sentences [det/noun/direct obj (det/noun/**adj**)/…]	Gender agreement task	Pleasant (7.6; 5.7), Unpleasant (2.4; 6.1), Neutral (4.9; 4.8)	x	✓	x	x	✓	x

Table 2
Means and SDs (in parentheses) of valence, arousal, number of letters (No. letters), number of syllables (No. Syllables) and lexical frequency of the neutral nouns and the unpleasant and pleasant adjectives.

		Valence	Arousal	No. letters	No. Syllables	Frequency (LogFreq)	Frequency (Zipf values)
Adjectives	Pleasant	7.60 (0.36)	5.71 (1.05)	7.80 (2.22)	3.56 (1.04)	0.90 (0.39)	3.81 (0.58)
(Target word)	Unpleasant	2.40 (0.65)	6.14 (0.64)	7.38 (1.91)	3.21 (0.83)	0.76 (0.43)	3.59 (0.62)
Nouns	Neutral	5.19 (0.53)	4.87 (0.59)	6.61 (1.71)	2.96 (0.76)	1.30 (0.55)	4.24 (0.63)

($M = 5.71$). Statistical analyses confirmed that unpleasant and pleasant adjectives differed in valence, [$t(47) = -35.03$, $p < .001$] but not in arousal [$t(47) = 1.71$, $p = 0.10$]. Moreover, all adjectives were chosen so as not to differ in number of letters [$t(47) = -0.72$, $p = .47$], number of syllables [$t(47) = 0.005$, $p = .79$], and lexical frequency [$t(47) = -0.54$, $p = .58$]. Table 2 shows the standard deviations and mean values of nouns and adjectives for number of syllables, number of letters, lexical frequency, valence, and arousal.

Importantly, the pleasant and unpleasant sentences were the same as used in Fraga et al. [14] (Experiment 2), all between 7 and 10 words long, with half of them showing gender agreement of the adjective with the head noun (match condition), and the other half showing a mismatch between these two constituents. Thus, four experimental conditions were created: 50 pleasant grammatically-correct sentences (pleasant-match condition), 50 pleasant grammatically-incorrect sentences (pleasant-mismatch condition), 50 unpleasant grammatically correct sentences (unpleasant-match condition); and, 50 unpleasant grammatically-incorrect sentences (unpleasant-mismatch condition). See below one example of each experimental condition:

2.2.1. Match-pleasant

El chico pintó un cuadro$_{[masc]}$ hermoso$_{[masc]}$ para su novia.

[The young man painted a beautiful$_{[masc]}$ painting$_{[masc]}$ for his girlfriend.]

2.2.2. Mismatch-pleasant

El chico pintó un cuadro$_{[masc]}$ hermosa$_{[fem]}$ para su novia.

[The young man painted a beautiful$_{[fem]}$ painting$_{[masc]}$ for his girlfriend.]

2.2.3. Match-unpleasant

Tania tiró el pescado$_{[masc]}$ podrido$_{[masc]}$ que estaba en la nevera.

[Tania threw away the rotten$_{[masc]}$ fish$_{[masc]}$ that was in the fridge.]

2.2.4. Mismatch-unpleasant

Tania tiró el pescado$_{[masc]}$ podrida$_{[fem]}$ que estaba en la nevera.

[Tania threw away the rotten$_{[fem]}$ fish$_{[masc]}$ that was in the fridge.]

Moreover, 100 filler sentences also used in Fraga et al.´s study [14] were included. These fillers were grammatical structures similar to that of the experimental sentences. In order to stave off the possibility of components overlapping, the critical word was never the last one in the sentence. Each participant was presented with a total of 300 sentences.

2.3. Procedure

Participants were seated in a comfortable chair in an enclosed room. The sentences were presented (word by word) at the center of a PC monitor situated at 100 cm from the participant's eyes. A chin rest was used in order to prevent head movements and also to keep distance from the screen constant. Words were displayed in black color on a gray background with a Chicago 30 font size. Participants performed a grammaticality judgement task. They were instructed to read the sentences silently. After reading each sentence, they had to press either M or Z on the keyboard to indicate whether the sentence was syntactically correct or incorrect (choice of letter was counterbalanced). A variable interval delay between 800–1000 ms initiated all trials, followed by three fixation crosses during 200 ms on the center of the screen. Then, each sentence was displayed word by word during 300 ms and a further 300 ms of inter-stimulus interval was used. When each sentence ended, three question marks were presented during 2500 ms indicating to the participants that they should give their response. If no answer was produced within that time span, the next trial began. Before the experimental trials, participants performed a three-trial training. The sentences were randomized in three blocks of 100 each with a brief resting period of 5 min between them. After the experimental session, participants completed a subjective evaluation questionnaire of the valence and arousal of the adjectives (by using an adaptation of the 1 to 9 scale of the *Self-Assessment Manikin* (SAM; [4]). Finally, they were asked to rate the whole sentences in valence, arousal and plausibility (by using a Likert-type 1 to 5 score; 1 being low, 5 being high). In total, each individual session took about 90 min.

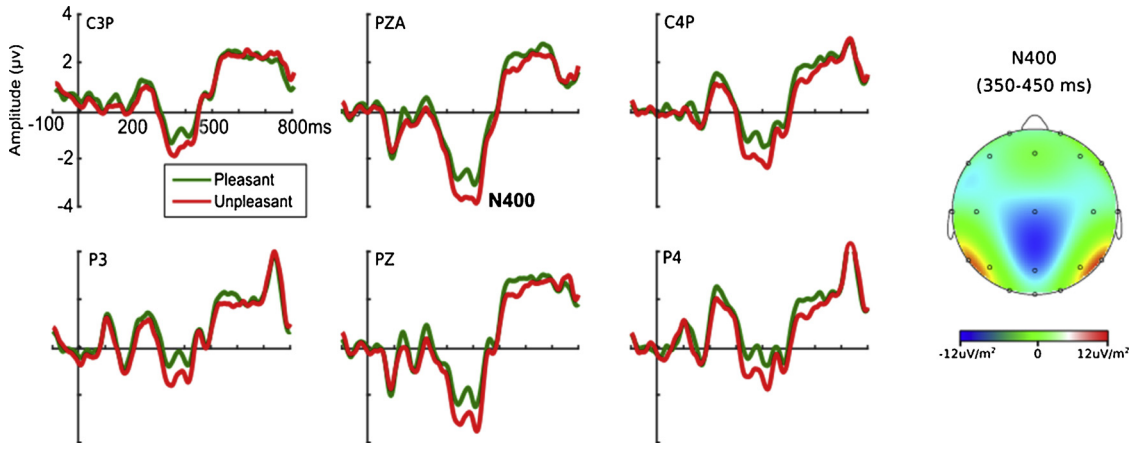

Fig. 1. Emotionality effects. Grand mean averaged ERP waveforms for pleasant and unpleasant adjectives collapsed across match and mismatch conditions at several electrode positions. Right: topographic voltage maps showing the scalp distribution of effects for the unpleasant and pleasant adjectives in the 350–450 time window.

2.4. Electrophysiological recording and analyses

The electroencephalogram (EEG) was recorded from 32 active electrodes mounted in an elastic cap (Electro-Cap International, Inc.). All electrodes were referenced online to the left and right earlobe and an electrode placed between the Fpz and Fz positions was used as the ground. Two electrodes placed on the muscles above and below the right eye orbital were used to record VEOG (vertical electro-oculogram). Electrode impedances were kept below 10 kΩ. The signals were digitized at a sample rate of 500 Hz, and a band-pass filter of 0.01–100 Hz was applied. EEG data was preprocessed using the *Brain Vision Analyzer® 2.3* software (Brain Products, Germany). Data were re-referenced offline to right and left earlobes average and a band-pass filter from 0.1 to 30 Hz (24 dB/oct.) was used. Stimulus-locked epochs of 1000 ms were extracted from continuous data beginning 100 ms prior to the critical adjective (that is, the adjectives inside the direct object noun-phrase). We used Independent Component Analysis to subtract correction for ocular artifacts [28]. Segments whose voltages went beyond ± 100 μV were eliminated. Finally, the baseline was corrected, and epochs were averaged for each of the four experimental conditions: pleasant match, pleasant mismatch, unpleasant match and unpleasant mismatch.

After visual inspection of the individual and grand-average waveforms, four early and middle time-windows were examined in order to explore the emotional effects: 80–130 ms (N100-P100 complex), 180–250 ms (P200), 200–300 ms (EPN) and 350–450 (N400). Likewise, based on previous findings on the LAN and P600/LPC components, two time-windows were selected for analyses: 350–450 ms and 500–700 ms after the onset of the adjective, respectively. For statistical analyses we grouped the electrodes into six regions of interest (ROIs): Left-Anterior (mean activity of Fp1, F3, F7, C3A, and C7A electrodes), Right-Anterior (Fp2, F4, F8, C4A, and C8A), Medial-Anterior (Fz, CzA, and Cz), Left-Posterior (T3L, C3P, T5, P3, and O1), Right-Posterior (T4L, C4P, T6, P4, and O2), and Medial-Posterior (PzA, Pz, and Oz). Mean amplitudes were selected as follows: MA and MP regions, and LP, MP and RP regions for the N100-P100, P200, EPN and N400 components; LA and RA regions for the LAN component; and MA and MP regions for the P600 component. Repeated measures ANOVAs were subsequently carried out on adjective emotionality and region, sentence grammaticality, and the interactions among these. Violations of the sphericity assumption were corrected when necessary by the Greenhouse-Geisser method. Additional pairwise comparisons of the values were performed (with Bonferroni correction adjustment) in those cases where ANOVAs showed effects of factors and interactions. The size of effects was calculated and reported in accordance with the partial η-square (η_p^2) method. Statistical analyses were carried out using the IBM *Statistica* software (version 10).

3. Results

3.1. Behavioral data

Statistical analyses (a 2 × 2 repeated measures ANOVA) of accuracy data revealed a main grammaticality effect [$F(1,25) = 52.76$, $p < .01$, $\eta_p^2 = .67$], showing that participants were more accurate in the match conditions (97%) than in the mismatch conditions (91%). Regarding RTs, a 2 × 2 repeated measures ANOVA also revealed a main grammaticality effect [$F(1,25) = 33.05$, $p < .01$, $\eta_p^2 = .57$], showing that participants were faster in the mismatch condition ($M = 433$ ms) than in the match condition ($M = 479$ ms), as well as an emotionality effect [$F(1,25) = 12.17$, $p < .01$, $\eta_p^2 = .32$], which showed that participants were faster in pleasant sentences ($M = 447$ ms) than in unpleasant sentences ($M = 465$ ms).

3.2. ERP data

Regarding the earliest time windows, no main effects of emotionality or of the interaction between emotionality and region were found in the three time-windows explored for the N100-P100, P200 and EPN components [$Fs(1,25) < 2$].

From the 300 ms window on, the unpleasant sentences elicited a negative deflection that peaked around 350 ms after the onset of the adjective with a maximum in parietal-posterior positions (N400). The grand mean ERPs for pleasant and unpleasant sentence conditions for several electrode positions are represented in Fig. 1. The statistical analysis, a three-factor repeated measure ANOVA (grammaticality x emotionality x laterality: LP, MP, RP) revealed main effects of grammaticality [$F(1,25) = 4.67$, $p = .040$, $\eta_p^2 = .15$], emotionality [$F(1,25) = 4.58$, $p = .042$, $\eta_p^2 = .15$] and laterality [$F(2, 50) = 15.94$, $p = .000$, $\eta_p^2 = .38$] as well as significant interactions between grammaticality and laterality [$F(2,50) = 8.67$, $p = .000$, $\eta_p^2 = .25$] and between emotionality and laterality [$F(2,50) = 3.41$, $p = .040$, $\eta_p^2 = .12$]. These effects showed that grammatically incorrect sentences evoked higher amplitudes ($M = -1.14$ μV) than grammatically correct ones ($M = -0.65$ μV). *Posthoc* analyses showed that such effects were only found in the LP region ($p = .0001$). Regarding the emotionality effects, the analyses showed that unpleasant sentences evoked a negative deflection with higher amplitudes ($M = -1.19$ μV) than pleasant sentences ($M = -0.61$ μV). *Posthoc* analyses showed that these effects were only found in MP and RP regions (both $p_s < .01$). A

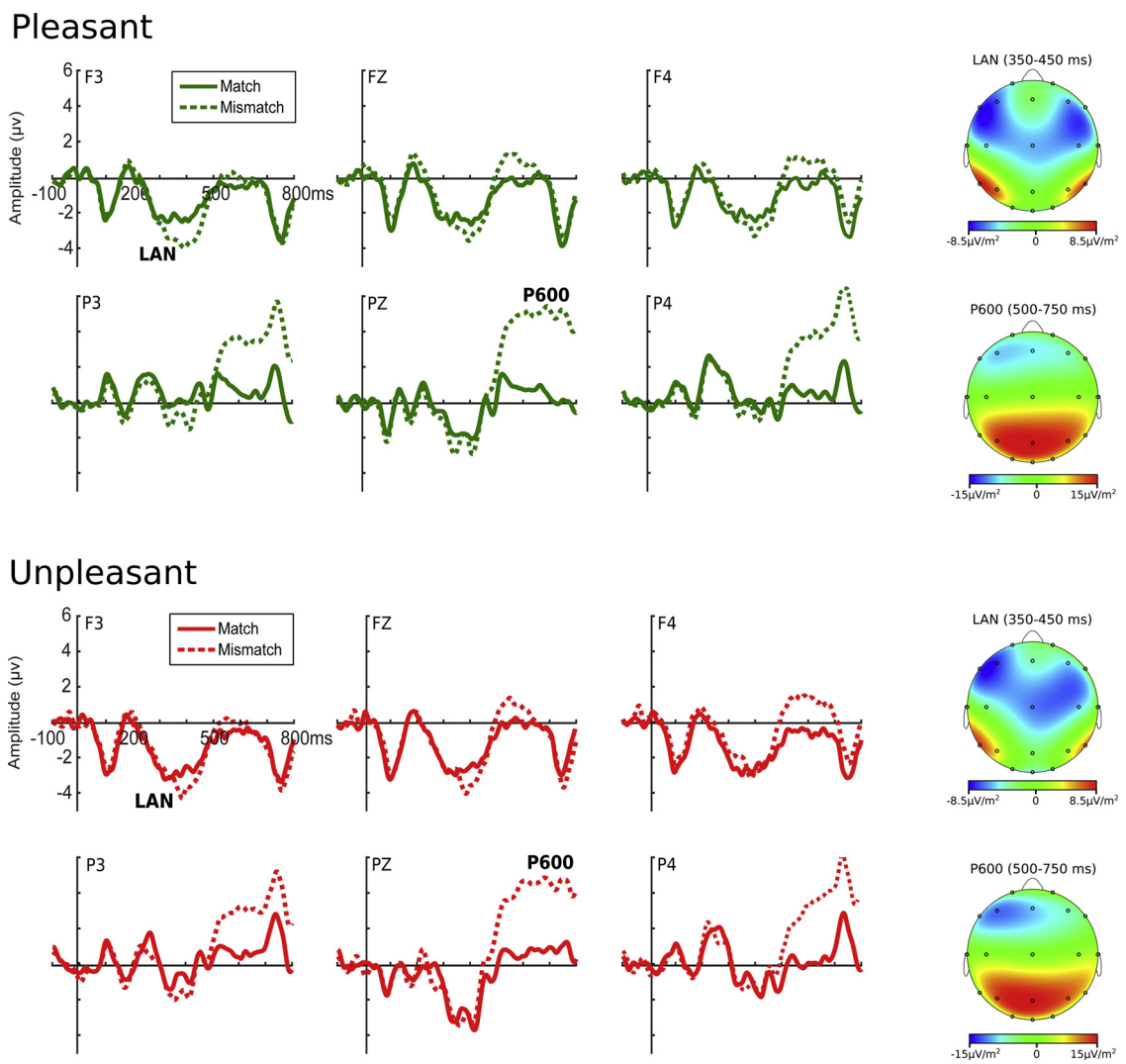

Fig. 2. Grammaticality effects. Grand mean averaged ERP waveforms for match and mismatch conditions elicited by pleasant and unpleasant adjectives, at several electrode positions. Right: topographic voltage maps showing the scalp distribution of effects for the match and mismatch conditions for unpleasant and pleasant adjectives in LAN and P600 time windows.

second three-factor repeated measure ANOVA (grammaticality x emotionality x caudality: MA and MP) did not show any significant effects [$Fs(1,25) < 2.5$].

The grand mean ERPs for match and mismatch sentence conditions for pleasant and unpleasant adjectives are represented in Fig. 2. As can be seen, both pleasant and unpleasant mismatch conditions evoked an anterior negativity (LAN) starting at about 300 ms after stimulus onset and peaking around 350 ms in left-frontal sites (see F3, F7 positions). The statistical analysis, a three-factor repeated measures ANOVA (grammaticality x emotionality x laterality: LA and RA) confirmed this pattern, since a main effect of grammaticality [$F(1, 25) = 7.61$, $p = .010$, $\eta_p^2 = .23$], laterality [$F(1, 25) = 7.49$, $p = .011$, $\eta_p^2 = .23$] and a grammaticality x laterality interaction [$F(1, 25) = 7.96$, $p = .009$, $\eta_p^2 = .24$] were found. These effects showed that grammatically incorrect sentences evoked a negative deflection with significantly higher amplitudes ($M = -2.20$ μV) than grammatically correct ones ($M = -1.55$ μV). Moreover, *posthoc* analyses showed that such effects were found in LA regions ($p = .0001$) but not in RA regions ($p = .70$). No other interactions or main effects were significant [$Fs(1,25) < 1$]. In sum, we observed similar LAN effects for the mismatch sentences both in the pleasant and the unpleasant conditions.

In the 500–800 ms time range, a positive deflection, the P600 component, was observed in the mismatch sentence conditions starting at about 550 ms after stimulus onset over centro-parietal positions (see Fig. 2). A three-factor repeated measures ANOVA (grammaticality x emotionality x caudality: MA and MP) revealed a main effect of grammaticality [$F(1,25) = 23.88$, $p = .000$, $\eta_p^2 = .48$], caudality [$F(1,25) = 4.35$, $p = .04$, $\eta_p^2 = .14$] and a grammaticality x caudality interaction [$F(1,25) = 5.89$, $p = .022$, $\eta_p^2 = .19$]. These significant effects showed that grammatically incorrect sentences elicited a positive deflection with significantly greater amplitudes ($M = 2.32$ μV) than grammatically correct sentences ($M = 0.13$ μV). In line with our previous studies, the *posthoc* analyses showed that the P600 component was more pronounced in MP regions ($M = 3.01$ μV) than in MA regions ($M = 1.63$ μV), ($p = .000$). No other main effects of emotionality [$F(1,25) = 1.01$, $p = .79$, $\eta_p^2 = .00$] or interactions [$Fs(1,25) < 1$] were found.

3.3. Rating studies

To examine whether participants' subjective ratings were consistent with the normative data (valence and arousal) of the adjectives, two 2 × 2 × 2 (list [list 1, list 2] × gender [feminine, masculine] × emotionality [pleasant, unpleasant]) repeated measures ANOVAs were performed. Regarding valence, these analyses revealed a main effect of emotionality [$F_1(1,24) = 308.35$, $p < .001$, $\eta_p^2 = .92$];

[$F_2(1,22) = 1393.6$, $p < .001$, $\eta_p^2 = .98$] showing that, as expected, pleasant adjectives were rated as more pleasant ($M = 7.10$) than unpleasant adjectives ($M = 2.70$). Regarding arousal, these analyses also revealed a main effect of emotionality [$F_1(1,24) = 20.49$, $p < .001$, $\eta_p^2 = .46$]; [$F_2(1,22) = 36.37$, $p < .001$, $\eta_p^2 = .62$] showing that, as in our previous studies, unpleasant adjectives were rated as more arousing ($M = 5.97$) than pleasant ones ($M = 4.96$).

Moreover, three 2 × 2 (gender [feminine, masculine] x emotionality [pleasant, unpleasant] repeated measures ANOVAs on valence, arousal and plausibility of the sentences were performed. The results of these analyses also revealed a main effect of emotionality on valence [$F_1(1,25) = 96.34$, $p < .001$, $\eta_p^2 = .79$]; [$F_2(1,48) = 127.68$, $p < .001$, $\eta_p^2 = .72$] and arousal [$F_1(1,25) = 5.77$, $p = .02$, $\eta_p^2 = .18$]; [$F_2(1,48) = 5.55$, $p = .02$, $\eta_p^2 = .10$], showing that participants rated the pleasant sentences as more pleasant ($M = 3.56$) and less arousing ($M = 3.04$) than the unpleasant ones ($M = 2.32$ and $M = 3.22$, respectively). As far as plausibility is concerned, the analysis revealed a main effect of emotionality [$F_1(1,25) = 59.02$, $p < .001$, $\eta_p^2 = .70$]; [$F_2(1,48) = 15.89$, $p < .001$, $\eta_p^2 = .24$] showing that participants rated the unpleasant sentences as slightly less plausible ($M = 4.12$) than the pleasant sentences ($M = 4.48$).

4. Discussion

In the present study we aimed to explore the effects of emotional words on morpho-syntactic processing during a gender agreement task. We manipulated the valence of the adjectives (pleasant vs unpleasant) and the syntactic congruency (agreement) of the adjective with the head noun in the NP included in long sentences. Behavioral data revealed that participants showed a better accuracy performance in match sentences than in the mismatch ones, although they also showed slower RTs. Moreover, these data revealed that the presence of pleasant words in the sentences speeded up responses regardless of the grammatical condition. This result is in line with the facilitation effects of positive stimuli frequently reported in various cognitive tasks [6,31]. As regards the ERP results, they showed main effects of emotionality, reflected in higher amplitudes of the N400 component for unpleasant adjectives, as well as grammaticality effects in the LAN and the P600 components, without any kind of interaction between grammaticality and emotionality in either of the two temporal windows.

The first goal of this study was to clarify which effects remain constant across experiments independently of the item list and context. That does not seem to be the case for early effects, since, unlike the study by Díaz-Lago et al. [10] we failed to find an effect of emotional valence in the earliest time windows, even though participants rated unpleasant sentences as more arousing than the pleasant ones. In any case, the average level of subjective arousal for the unpleasant words was 5.97, and this still seems to be too low to capture early attention during the performance of a task that focuses on agreement processes. As a matter of fact, in Fraga et al. [14] no early emotional effects were found for either unpleasant adjectives vs neutral ones (Experiment 1), or unpleasant and pleasant adjectives vs neutral ones (Experiment 2). In a similar way, Martín-Loeches et al. [34] and Hinojosa et al. [24] also failed to find early effects.

Regarding the subsequent time-windows, our results showed higher amplitudes for unpleasant adjectives that were obtained around 350 ms after the onset of the target word. This N400 effect confirms that unpleasant words were probably more difficult to be semantically integrated than pleasant words in the context of the sentence, as has been found in previous studies [23,41], although we cannot completely rule out the possibility that this result might be derived from the higher implausibility of the unpleasant sentences as estimated by the participants. Nonetheless, we do not think that was the case, firstly because negative sentences were rated with an average of 4.12 in the plausibility 1–5 scale, and secondly, because moderately arousing negative words tend to be recognized more slowly than neutral, positive, and even highly arousing negative ones [15,25]. Furthermore, in line with our previous works [10,14], we also obtained higher amplitudes for the mismatch than for the match conditions in both the intermediate and late time components, thus confirming the LAN/P600 biphasic pattern of neural correlates of gender agreement error processing. The P600 effect has also been consistently reported in other similar ERP studies [24,34]. However, unlike Díaz-Lago et al. [10] we did not observe an LPC component in this time window. In as much as the P600 component is related to a later, voluntary re-analysis of the syntactic error [1,36], our results support the view that, in the presence of pleasant and unpleasant words, this reanalysis is not influenced by the affective valence of the adjectives which contain the gender error.

Our second goal was to examine whether the LAN grammaticality effect interacts or fails to interact with the emotionality of the word. The relevance of this quest is to be measured in the context of a classic branch of psycholinguistic research that revolves around whether grammatical processes (such as adjunction of modifiers to a head, agreement between a controller and a target, syntactic ambiguity resolution, etc.) are encapsulated from semantic dimensions (such as animacy, concreteness or numerosity) in a modular fashion [13]. Strictly speaking, however, the pleasantness vs unpleasantness elicited by specific lexical items is not even semantics but encyclopaedically-accrued pragmatic knowledge (of the world) [45]. Should this type of knowledge interface with grammar, then the modularity hypothesis (i.e., the view that grammar is separate from general cognitive mechanisms and principles) would be seriously compromised indeed. Although some recent research suggests this may be the case, we obtained a LAN effect for the ungrammatical sentences along with a N400 emotionality effect for unpleasant words, yet no interaction between grammaticality and emotionality. Therefore, our results provide new evidence that, in a sentence context, affective valence and gender agreement are processed in parallel, without any kind of interference or facilitation between the two. Hence, they give support to the *Syntactic Encapsulation Hypothesis* [19,21], which assumes that grammar processes run in an autonomous and encapsulated way and go against other studies in the field that align with the interference hypothesis [24,27,34].

As regards our third goal, the comparison between pleasant and unpleasant words showed that, although moderately unpleasant and pleasant words were processed at the same time (after around 400 ms) and that both of them were unable to affect morphosyntactic operations in the gender grammaticality judgment task, unpleasant words (either because of its negative valence or because of its lower plausibility) showed a stronger difficulty to be semantically integrated in the whole sentence. This result fits well with the later behavioral facilitation effects found for pleasant words.

Finally, as noted by Fraga [44] it is important to take into account that in this emerging line of research, in which grammaticality and emotionality are crossed in ERP studies, new studies are needed to test the influence of other critical variables, such as the size of the linguistic units employed (phrases, sentences, etc.), the morphosyntactic feature to be processed (gender, number, person), or the grammatical category and the arousal level of the emotional words that fill those units.

Acknowledgments

The present study was supported by the Spanish Ministry of Economy and Competitiveness and the Fondo Europeo de Desarrollo Regional (MINECO/FEDER; Grant Nos. PSI2015-65116-P) and a research grant from the Autonomous Government of Galicia (Consellería de Educación, Xunta de Galicia, grant code GRC 2015/006).

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