How the speaker's emotional facial expressions may affect language comprehension

Article · October 2022

DOI: 10.1080/23273798.2022.2130945

11 authors, including:


David Hernández-Gutiérrez
Basque Center on Cognition, Brain and Language


Francisco Muñoz
Complutense University of Madrid


Zahra Khosrowtaj


Werner Sommer
Humboldt-Universität zu Berlin

LANGUAGE, COGNITION AND NEUROSCIENCE
https://doi.org/10.1080/23273798.2022.2130945

Routledge
Taylor & Francis Group

REGULAR ARTICLE

How the speaker's emotional facial expressions may affect language comprehension

David Hernández-Gutiérrez [a,b], Francisco Muñoz [a,c], Zahra Khosrowtaj [d], Werner Sommer [e], Laura Jiménez-Ortega [a,c], Rasha Abdel Rahman [e], José Sánchez-García [a], Pilar Casado [a,c], Sabela Fondevila [a,c], Javier Espuny [a] and Manuel Martín-Loeches [a,c]

[a]Center UCM-ISCIII for Human Evolution and Behaviour, Madrid, Spain; [b]Basque Center on Cognition, Brain and Language (BCBL), Donostia/San Sebastián, Spain; [c]Department of Psychobiology & Methods for the Behavioural Sciences, Complutense University of Madrid, Madrid, Spain; [d]Department of Psychology, University of Marburg, Marburg, Germany; [e]Department of Psychology, Humboldt Universität zu Berlin, Berlin, Germany

ABSTRACT

During communicative face-to-face interactions, emotional expressions are typically processed along with auditory speech. Although previous research has demonstrated the interaction between emotion and linguistic processes, so far no study has focused on the effect of the speaker's emotional facial expression on natural language processing. In the present event-related potential (ERP) study, participants listened to spoken sentences while seeing the portrait of the speaker's face with either happy, neutral, or fearful emotional expression. In Study 1A, the N400 effect, a neural marker of semantic comprehension, was unaffected by the speaker's emotional expression. In Study 1B, we manipulated morphosyntactic agreement. The P600 effect was boosted by the happy emotional expression. This may be interpreted as reflecting additional effort in linguistic reanalysis, in line with the heuristic processing style that characterises positive emotions. The present results demonstrate an influence of the speaker's emotional facial expressions on non-emotional language processing during audiovisual communicative interactions.

ARTICLE HISTORY
Received 25 January 2022
Accepted 13 September 2022

KEYWORDS
Multimodal language; emotional facial expression; syntax; semantics; P600

1. Introduction

Language can be considered a multimodal human adaptation that evolved by means of communicative pressures (Gibson et al., 2019). Since the information processed during communicative interactions usually derives from a speaker, we can refer to *socially situated language comprehension* (Münster & Knoeferle, 2018). Within this situational context, faces are a distinctive type of stimuli. Hence, both visual and social information derived from emotional facial expressions play a major role in the communicative processes, facilitating the recognition of the speaker's mental state (Somerville et al., 2011). Extending current research, the present study investigates the effects of a speaker's emotional facial expression on semantic and syntactic processing during listening to connected speech, using event-related brain potentials (ERPs) as the main research tool.

The interplay between language and emotion is widely accepted (Hinojosa et al., 2020). By employing different tasks and techniques, behavioural studies have demonstrated influences of emotion on language processing. However, there is still a lack of consensus on the direction of the effects. For instance, in a lexical decision task using the "mouse tracking" technique, the processing of positive words was facilitated compared to negative and neutral words (Crossfield & Damian, 2021). In another study using a word recognition task, both positive and negative valence of words facilitated performance (shorter reaction times) compared to neutral words, presumably because of increased motivational relevance (Kousta et al., 2009). Comparable results have been obtained in sentence contexts. Particularly, eye movements revealed shorter fixation times on emotion-laden words (Scott et al., 2012). In Chinese reading, fixation durations were affected by emotional words that were still in the parafovea (Yan & Sommer, 2015, 2019). However, contrary evidence was found too. Hence, in a lexical retrieval task, participants were found slower naming pictures with negative and positive valence compared to neutral pictures (Blackett et al., 2017).

Neuroimaging research suggests common neural substrates of the processing of language and emotional facial expressions, namely, the superior temporal sulcus

CONTACT David Hernández-Gutiérrez dhernandez@bcbl.eu Basque Center on Cognition, Brain and Language (BCBL), Paseo Mikeletegi 69, 2°, 20009 Donostia/San Sebastián, Spain

(STS), a multimodal cortical area (Barraclough et al., 2005). Engell and Haxby (2007) observed that this region appeared more strongly activated during the perception of emotional as compared to faces with neutral expression. Further, the STS was more activated during a semantic decision task about spoken words as compared to listening to nonlinguistic sounds (Binder et al., 1997), as well as in the processing of syntactically complex relative to linear sentences (Friederici et al., 2009). The involvement of the STS in both facial and linguistic information (syntactic and semantic) suggests that it may be critical integrating multimodal language and emotional information. Similarly, the anterior temporal lobe (ATL) plays a role in integrating both multimodal linguistic information and emotion. This region has been proposed as a transmodal semantic hub (Patterson & Lambon Ralph, 2016). Moreover, emotion-related structures like the amygdala or the orbitofrontal cortex connect with the ATL through the uncinate fasciculus (Olson et al., 2013), which is also involved in syntactic combinatory operations (Friederici et al., 2006). Overall, there is support for a possible interaction between emotional facial expressions and language comprehension at the semantic and syntactic levels.

Electrophysiological evidence increasingly demonstrates that online language comprehension may be modulated by emotion, as will be reviewed below. The ERP technique provides fine-grained temporal resolution for the study of language in emotional contexts. The N400, the LAN, and the P600 components of the ERP are well-known indices of language-related processing. The N400 is a centro-parietal component, peaking around 400 ms after stimulus onset (Schöne et al., 2018; Van Petten, 2014). It is sensitive to the congruency of a word with preceding information (Payne et al., 2015) and to contextual constraints, probably reflecting semantic processing efforts (Kutas & Federmeier, 2011). The left-anterior negativity (LAN) is considered as an index of first-pass syntactic processes appearing about 300 ms after a morphosyntactic mismatch (Friederici, 2011; Molinaro et al., 2011). Syntactic reanalysis or repair is indexed by the P600 (Friederici, 2011), a centro-parietally positive-going component typically peaking around 600 ms after stimulus onset.

Semantics and syntax may be differentially affected by both emotional valence (positive, neutral, and negative) and by the moment at which the emotional stimulus is provided. In the syntactic domain, Martín-Loeches et al. (2012) manipulated both the morphosyntactic correctness and the emotional valence of critical words in a sentence context. They found the largest LAN effect to morphosyntactically incorrect and emotionally negative words, but an attenuation of this component for emotionally positive words as compared to neutral ones. Overall, the main findings for positive stimuli within the sentence were interpreted based on a shift from *analytic* to *heuristic* processing strategies (Holt et al., 2009), that is, the linguistic processor may take a shortcut, not using all linguistic information available to complete the syntactic parsing. In contrast, negative stimuli may trigger a more analytic processing strategy (Bless & Schwarz, 1999; Gasper & Clore, 2002; Isen, 2001). However, other studies using sentences did not find significant modulations of the LAN amplitude by emotion, neither when comparing pleasant with neutral critical words (Díaz-Lago et al., 2015) nor to the comparison of unpleasant words with neutral words (Experiment 1; Fraga et al., 2017). Moreover, no significant LAN modulations were found when the three conditions (positive, neutral, and negative) were compared together (Experiment 2; Fraga et al., 2017), with similar arousal levels for positive and negative words. In this line, a recent study reported similar LAN effects to gender mismatches in moderately arousing positive and negative words within sentences (Padrón et al., 2020). Although no control condition (neutral words) was included in this study, the results suggest that the arousal factor may be important to understand emotional modulations of syntax processing. Interestingly, the LAN is typically enhanced when the presentation of the emotional stimulus – regardless of its emotional valence – precedes sentence processing (Espuny et al., 2018; Jiménez-Ortega et al., 2012).

The P600 component does not seem to be biased by preceding or current emotion processing. For instance, Díaz-Lago et al. (2015), Fraga et al. (2017), Jiménez-Ortega et al. (2017, 2021) – using subliminal presentation – Martín-Loeches et al. (2012), and Padrón et al. (2020), did not observe modulations of the syntactic P600 effect by the emotional content within the sentence. Similarly, Jiménez-Ortega et al. (2012) and Espuny et al. (2018) did not observe significant modulations of the P600 when emotion-laden language preceded morphosyntactic violations. In contrast to these results, the presentation of happy or sad video clips preceding the presentation of neutral sentences containing morphosyntactic subject-verb disagreements yielded a positive effect of happy mood on the P600 amplitude, and a negative effect of sad mood (Vissers et al., 2010). These results were supported by Verhees et al. (2015), who argued that a happy mood fosters heuristic processing, leading to a more superficial processing of morphosyntactic mismatches, consequently requiring more reanalysis, hence enhancing the P600 effect. The opposite may be the case in sad mood, where a more detailed first-pass analysis diminishes the necessity for reanalysis and therefore decreases the P600 effect.

In the semantic domain, Martín-Loeches et al. (2012) used sentences containing emotion-laden words of positive, neutral, or negative valence that were either semantically congruent or incongruent with the – emotionally neutral – semantic context. Note that semantic congruence was orthogonal to emotional valence. No interaction was found between the N400 effect and the valence of the words. A similar pattern was reported when emotional paragraphs preceded the processing of semantically coherent and incoherent neutral sentences (Jiménez-Ortega et al., 2012). In contrast, Federmeier et al. (2001) manipulated the participant's mood state with positive or neutral pictures preceding the presentation of neutral sentences and found that positive mood significantly reduced the N400 to semantic violations. However, Chwilla et al. (2011) reported a reduction of the N400 for sad mood as compared to happy mood, manipulated by means of film clips shown prior to sentences presentation.

The studies reviewed above did not explicitly consider interpersonal communicative contexts. In everyday life such contexts are frequently provided by the speaker, conveying many cues, ranging from visual speech, facial and bodily emotional expressions, and attention cues (gaze direction, posture), as well as identity-mediated semantic information, which, in turn, may have strong emotional connotations. Hence it is feasible to use the speaker's face in psycholinguistic research to investigate the influence of emotions as communicative signals. In this regard, previous studies by the present authors have focused on the effects of simulated communicative contexts on language processing by situating speech comprehension within face-to-face visual contexts (Hernández-Gutiérrez et al., 2018, 2021). It was found that the mere presence of the speaker's face while listening to sentences impacts semantic processing. This was evidenced in a larger N400 effect compared to a non-social control condition, where a scrambled face was presented as a control stimulus (Hernández-Gutiérrez et al., 2021). Interestingly, in another study that investigated whether the speaker's facial movements facilitate semantic comprehension, we did not find such an effect when comparing the processing of auditory sentences accompanied by either a video of the speaker's face or a still image of his face (Hernández-Gutiérrez et al., 2018). However, when listening to expected sentences, a late posterior positivity (LPP) emerged in the dynamic condition. Therefore, audiovisual social communication presumably enhanced motivated attention to the communicative context when language was "easy" to process, otherwise, neural processing of language should be prioritised. In a series of studies, Xu and co-workers showed that the speaker's face (and voice) influenced syntactic processing, modulating the P600 component, presumably moderated by the perceived language competence of the speaker (Xu et al., 2020, 2021a, 2021b). Although unrelated to emotion, these studies strongly indicate that the social-communicative context exerts an influence on language processing.

In the present study, we investigated the effect of emotion on language processing framed within a simulated social context. Because of the relevance of the speaker within the communicative perspective of language, face-to-face situational contexts were expected to increase the emotional effects on language comprehension. We carried out two sub-studies separately, examining the semantic and the syntactic domains. In both sub-studies participants listened to the sentences while viewing a static picture of the speaker's face with one of three emotional expressions: happy, fearful, or neutral.

In Study 1A, we manipulated the semantic congruence of critical words embedded in emotionally neutral, naturally spoken sentences. Considering the results from previous studies and the face-to-face context, which may strengthen the effects of emotion, we expected significant effects of emotional expressions on semantic processing of emotionally neutral sentences. However, because of mixed evidence, predictions cannot be straightforward at this stage. In this regard, while no modulation of the N400 effect by emotion might be expected (e.g. Jiménez-Ortega et al., 2012; Martín-Loeches et al., 2012), the effects might be boosted by our present manipulation, resembling the findings reported by Federmeier et al. (2001), or they might even be reduced, in line with Chwilla et al. (2011).

In Study 1B, employing the same participants, stimuli, and experimental procedures as in Study 1B, we manipulated the morphosyntactic correctness of target words. In line with previous findings, we expected that fearful faces, as compared to happy and neutral expressions would elicit the largest LAN amplitude, because of a detailed first-pass morphosyntactic processing. Furthermore, we predicted reduced or no LAN effects for happy as compared to neutral and fearful expressions. Although some previous experiments had not found significant modulations of the P600 with non-face stimuli, we expected facial expressions to affect this component due to their often powerful effects. Consequently, if happy speaker expressions foster heuristic morphosyntactic processing, we predicted larger P600 effects compared to neutral faces because a deeper reanalysis will be necessary. In turn, the P600 would be reduced by fearful speaker faces because negative emotions might trigger an analytic processing style facilitating the detection of morphosyntactic errors, enhancing the LAN but diminishing the need for reanalysis, reflected in the P600.

2. Study 1A: semantic domain

2.1. Methods

2.1.1. Participants

Thirty native Spanish speakers participated in both sub-studies (15 males, 15 females; age range 18–25 $M = 19.8$, $SD = 2.3$); all were right-handed (mean Oldfield scores + 65; Oldfield, 1971) and reported normal or corrected to normal vision and hearing, and the absence of psychological problems. Participants gave written informed consent and were reimbursed with 15€. The study was performed in accordance with the Declaration of Helsinki and approved by the Hospital Clínico (Madrid) ethic committee.

2.1.2. Materials and procedure

The language stimuli consisted of 960 Spanish sentences (480 correct and 480 semantically incongruent versions) with three different structures. Critical words could be adjectives (Structure 1) or nouns (Structures 2 and 3). The same materials had previously been used by Hernández-Gutiérrez et al. (2021), where elicited clear N400 effects. Examples of the linguistic stimuli are provided below. Critical words are boldfaced, and English translations are presented in brackets.

Structure 1 ($n = 300$): [Det]-[N]-[**Adj**]-[V]-[Prep]-[N]

- Congruent: *El pañuelo* ***bordado*** *era de mi abuela* (The **embroided** cushion belonged to my grandmother)

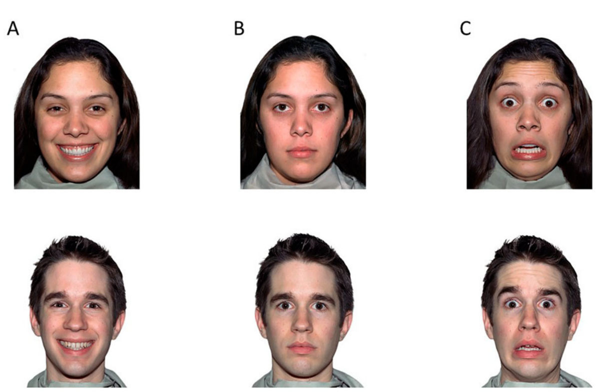

Figure 1. Emotional visual stimuli. Pictures of the female and male speakers with the three different facial expressions: happy (a), neutral (b) and fearful (c).

- Incongruent: *El pañuelo* ***asado*** *era de mi abuela* (The **roasted** cushion belonged to my grandmother)

Structure 2 ($n = 90$): [Det]-[N]-[V]-[Det]-[**N**]-[Adj]

- Congruent: *Los turistas habían fotografiado los* ***glaciares*** *árticos* (The tourists had photographed the arctic **glaciers)**
- Incongruent: *Los turistas habían fotografiado los* ***pensamientos*** *árticos* (The tourists had photographed the arctic thoughts)

Structure 3 ($n = 90$): [Det]-[N]-[V]-[Prep]-[Det]-[**N**]-[Prep]-[Det]-[N]

- Congruent: *Las hojas son recogidas durante el* ***otoño*** *por los barrenderos* (The leaves are picked by the sweepers during the **autumn**)
- Incongruent: *Las hojas son recogidas durante el* ***escritor*** *por los barrenderos.* (The leaves are picked by the sweepers during the **writer**)

Sentences were spoken with neutral prosody by a male and a female speaker. ERP triggers were placed at the onset of target words with GoldWave© software by three different researchers, considering both the auditory and visual (spectrogram) patterns of the sound waves. The final trigger for each word was the average of the three values. The length of target words varied between two and five syllables, and linguistic characteristics like word frequency, concreteness, imageability, familiarity and emotional content were controlled by presenting every target word and its associated sentences in both voices across all experimental conditions. The cloze probability was calculated for congruent and incongruent target words with a questionnaire showing the printed sentence fragments preceding the target words, which was completed by 64 raters who did not participate in the study. Congruent target words were predicted in 8.4% of all fragments, while incongruent words were never predicted.

The spoken sentences were accompanied by a picture of the (fictitious) speaker's face with either happy, fear or neutral (control condition) emotional expression (see Figure 1). Three pictures of the male and the female speaker were taken from the NimStim set of facial expressions (Tottenham et al., 2009). Each face was assigned to the voice of the corresponding sex; this correspondence was maintained throughout the study.

The two sub-studies were performed in counterbalanced order in an electrically shielded cabin and took 25 min each. Participants sat in a comfortable chair facing a computer screen (1280 × 1024 pt) at a viewing distance of 60 cm. Auditory stimuli were presented via two shielded speakers placed at each side of the screen. Sound pressure level was always the same and all participants confirmed that the loudness was comfortable. Every participant listened to 240 sentences evenly distributed to six conditions: 40 congruent and 40 incongruent sentences, combined with happy, fearful, and neutral expressions of the speaker's faces. Each sentence was presented to a given participant only once. Note that in Study 1A, participants were presented only with 240 out of the total 480 sentences because they also participated in Study 1B, where they received the other 240 sentences. Sentence assignment to experiment was counterbalanced. The types of facial expression (happy, neutral, fearful) and sentences (congruent, incongruent) were mixed in random order. The experimental session included three breaks, one after every 60 sentences.

We constructed six presentation sets of 240 sentences each to cover all possible combinations between semantic congruency and facial expression. Five participants were assigned to each presentation set, and the presentation order of sentences within each set was randomised. Although each participant heard a given sentence spoken only by one of the speakers, across all participants, every sentence was presented in both the male and female voice; hence, experimental effects cannot be attributed to a particular linguistic sentence structure or voice.

Participants were informed that they would hear sentences while seeing the face of the speaker. They should press one of two buttons with the left or right hand after each sentence to indicate whether it made sense or not. The assignment of judgment (yes/no) and response button was counterbalanced across participants. At the beginning of each trial, the speaker's face appeared in the centre of the screen. After 500 ms the audio presentation started. The face was presented on the screen until the end of the sentence; after 1s, a question mark appeared at the centre of the screen, prompting the participant to respond. Participants were asked not to blink while the sentences were presented.

2.1.3. EEG recording and data analysis

The EEG was recorded from 59 cephalic electrodes placed within an elastic cap according to the international 10–20 system; impedances were kept below 5 kΩ. Vertical (VEOG) and horizontal (HEOG) bipolar ocular electrodes were used to record blinks and horizontal eye movements, respectively. Initially, EEG recordings were referenced to the right mastoid. Raw data were sampled at 250 Hz and recorded with a band-pass from 0.01 to 100 Hz. Offline, the EEG was re-referenced to average mastoids and filtered with a band-pass from 0.1 to 15 Hz. EEG epochs of 1100 ms were segmented from the continuous EEG data, starting 200 ms before the critical word onset. The correction of ocular artefacts (vertical and horizontal eye movements) was conducted with Independent Component Analysis (ICA). The rejection of the remaining artefacts was performed semi-automatically, removing trials exceeding a range of 100 µV and others by visual inspection. Overall, the mean rate of rejected trials was 18%. ERPs were computed only for trials with correct judgements.

A 200-ms post-stimulus baseline was applied. This has previously been used in other studies (e.g. Hernández-Gutiérrez et al., 2021). Since target words were presented within connected-speech sentences, ERPs in the congruent and incongruent conditions may diverge before the onsets of critical words. Therefore, a post-stimulus baseline ensures that differences between conditions on the N400 amplitude are related to experimental manipulations.

A first visual inspection of grand average ERPs confirmed the presence of an N400 effect with a central topography between about 300 and 600 ms (see Figure 2). To measure the N400 effect, we selected a central ROI consisting of nine electrodes: FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, and CP2. The averaged amplitude across all ROI electrodes was used in the statistical analyses. We conducted a 2 (Semantic congruency: congruent vs. incongruent) × 3 (Emotional expression: positive vs. neutral vs. fearful) repeated-measures analysis of variance (ANOVA). The ANOVA was performed on average amplitudes within the 300–600 ms time window, based on a previous study with the same language material (Hernández-Gutiérrez et al., 2021); visual inspection of the difference waveforms and the scalp distribution of the effect confirmed this critical time window. Greenhouse-Geisser corrections were applied when appropriate.

2.2. Results and discussion

The average error rate in the semantic congruency task was 11.01%. The ANOVA did not yield significant main effects of Semantic Congruency (F (1, 29) = 0.58; p = .45; η^2 = .02; π = .11), Emotional Expression (F (2, 58) = 1.09; p = .33; η^2 = .04; π = .21), or interaction of these factors (F (2, 58) = 0.33; p = .66; η^2 = .01; π = .1). Descriptively, mean reaction times were longest after neutral facial expressions (M = 429.04 ms), followed by fearful (M = 415.23 ms) and happy expressions (M = 413.98 ms), but the factor Emotional Expression was not significant (F (2, 58) = 2.53; p = .09; η^2 = .00; π = .49). Further, no main effect of Semantic congruency (F (1,

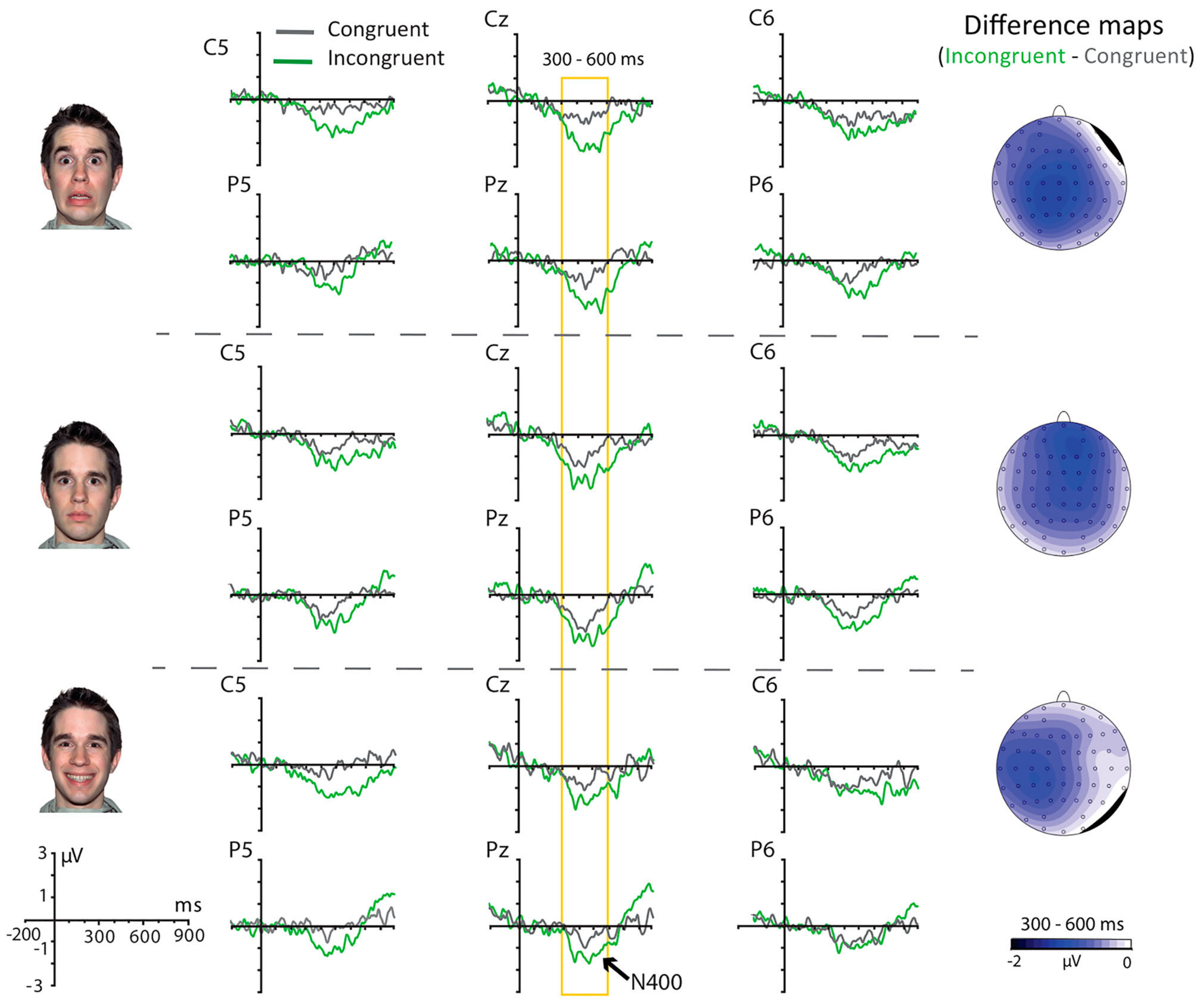

Figure 2. Congruency effects for each Emotional Expression. The difference maps represent the Congruency effect (incongruent minus congruent) for each emotion in the N400 time window.

29) = 0.45; $p = .83$; $\eta^2 = .00$; $\pi = .06$) or interaction of Semantic Congruency and Emotional Expression (F (2, 58) = 0.35; $p = .98$; $\eta^2 = .00$; $\pi = .05$) were found.

In ERPs the N400 effect displayed a broad topographical distribution, being maximal at central electrodes for happy and fearful emotional expressions (see Figure 2). ANOVA confirmed the effect of Semantic Congruency in the N400 window (F (1, 29) = 23.75; $p < .001$; $\eta^2 = .45$; $\pi = .1$). Emotional Expression (F (2, 58) = 1.95; $p = .15$; $\eta^2 = .06$; $\pi = .39$), did not a yield significant main effect or interaction with Semantic Congruency (F (2, 58) = 0.55; $p = .58$; $\eta^2 = .02$; $\pi = .14$). For neutral faces, the amplitude appeared maximal at frontal sites (Fz). To explore the possibility that the influence of emotion on the N400 depends on the scalp site, planned analysis were performed for two ROIs around Fz and CPz electrodes. The frontal ROI included the electrodes F1, Fz, F2, FC1, FCz and FC2, and the centro-parietal ROI included the electrodes CP1, CPz, CP2, P1, Pz and P2. The three-way interaction Emotional Expression by Semantic Congruency by ROI did not yield a significant result, hence did not support different N400 amplitudes between emotions in frontal and central scalp sites (F (2, 58) = 0.18; $p = .81$; $\eta^2 = .03$; $\pi = .12$).

Overall, the N400 effect was not sensitive to the speaker's emotional facial expression. Therefore, the present results do not support the hypothesis that emotional facial expressions in communicative contexts have a relevant effect on the semantic processing of speech, which is in line with previous negative results with written emotion-laden language stimuli (Jiménez-Ortega et al., 2012; Martín-Loeches et al., 2012). In sum, the N400 was not significantly affected, indicating similar efforts in the processing of semantic incongruencies (Kutas & Federmeier, 2011) when facing emotional and neutral speakers.

3. Study 1B: syntactic domain

3.1. Methods

3.1.1. Participants

Participants were the same as in Study 1A.

3.1.2. Materials and procedure

The 480 correct sentences used in Study 1A were modified to include a morphosyntactic violation of gender or number in critical words. Depending on the structure of the sentence, there could be a noun–adjective mismatch (Structure 1) or determiner-noun mismatch (Structures 2 and 3). In our previous study (Hernández-Gutiérrez et al., 2021), these morphosyntactic mismatches elicited both LAN and P600 components. Examples of the sentences and their English translations are provided below (critical words in brackets).

Structure 1 ($n = 300$): [Det]-[N]-[**Adj**]-[V]-[Prep]-[N]

- Correct: El pañuelo$_{Masc/Sing}$ **bordado**$_{Masc/Sing}$ era de mi abuela

  (The **embroided**$_{Masc/Sing}$ cushion$_{Masc/Sing}$ belonged to my grandmother)
- Incorrect: El pañuelo$_{Masc/Sing}$ **bordada**$_{Fem/Sing}$ era de mi abuela

  (The **embroided**$_{Fem/Sing}$ cushion$_{Masc/Sing}$ belonged to my grandmother)

Structure 2 ($n = 90$): [Det]-[N]-[V]-[Det]-[**N**]-[Adj]

- Correct: Los turistas habían fotografíado los$_{Masc/Plur}$ **glaciares**$_{Masc/Plur}$ árticos.

  (The tourists had photographed the$_{Masc/Plur}$ arctic **glaciers**$_{Masc/Plur}$)
- Incorrect: Los turistas habían fotografiado los$_{Masc/Plur}$ **glaciar**$_{Masc/Sing}$ árticos

  (The tourists had photographed the$_{Masc/Plur}$ arctic **glacier**$_{Masc/Sing}$**)**

Structure 3 ($n = 90$): [Det]-[N]-[V]-[Prep]-[Det]-[**N**]-[Prep]-[Det]-[N]

- Correct: Las hojas son recogidas durante el$_{Masc/Sing}$ **otoño**$_{Masc/Sing}$ por los barrenderos

  (The leaves are picked by the sweepers during the$_{Masc/Sing}$ **autumn**$_{Masc/Sing}$)
- Incorrect: Las hojas son recogidas durante el$_{Masc/Sing}$ **otoños**$_{Masc/Plur}$ por los barrenderos.

  (The leaves are picked by the sweepers during the$_{Masc/Sing}$ **autumns**$_{Masc/Plur}$)

Participants listened to 240 sentences, all different to the ones that had been presented to them in Study 1A. Since the critical information for morphosyntactic violations relates to the gender/number markers, triggers for critical words were set at the offset of the lexeme, just before the gender/number declension, following the same procedure as in Study 1A (average of 3 different judgements).

The experimental procedure was the same as in Study 1A, but participants performed a morphosyntactic correctness judgment after each sentence. Study 1B also took 25 min and was separated from Study 1A by a 10-min break.

3.1.3. EEG recording and data analysis

The characteristics of the EEG recordings were identical to Study 1A.

Overall, the mean rate of rejected trials was 13%. A visual inspection of the ERPs confirmed the presence of LAN and P600 effects (Figure 3). We performed 2 (morphosyntactic correctness: correct vs. incorrect) × 3 (emotional expression: positive vs. negative vs. neutral) repeated-measures ANOVAs for two ROIs, based on our previous study with the same material (Hernández-Gutiérrez et al., 2021) and on visual inspection. The LAN was measured in the time interval 250–400 ms after morphosyntactic declension onset, in a ROI consisting of six electrodes: F3, FC3, FC5, T7, C3 and C5. The P600 amplitude was measured in two consecutive time windows: 450–650 and 650–850 ms. In line with our previous study (Hernández-Gutiérrez et al., 2021), we decided to split the P600 into two intervals since they have been proposed to reflect two-functionally different processing stages (Molinaro et al., 2011). Analyses were performed within a ROI consisting of ten electrodes: P3, P1, Pz, P2, P4, PO3, PO4, CP1, CPz, and CP2. The averaged amplitudes of the electrodes within a given ROI were used as dependent variables. Bonferoni-corrected posthoc pairwise comparisons were applied to significant interactions. Otherwise, data processing was the same as in Study 1A.

3.2. Results and discussion

The mean error rate in the morphosyntactic correctness task was 2.26%. The ANOVA of error rates revealed a significant effect of Morphosyntactic Correctness (F (1,29) = 5.95; $p = .02$; $\eta^2 = .17$; $\pi = .65$), with slightly more errors after incongruent than congruent sentences ($M = 2.76$ vs. 1.77%). Emotional Expression did not yield a significant main effect (F (2,58) = 0.1; $p = .99$; $\eta^2 = .00$; $\pi = .05$), nor interaction with Morphosyntactic Correctness (F (2, 58) = 0.46; $p = .64$; $\eta^2 = .02$; $\pi = .12$).

For reaction times, the ANOVA revealed a significant main effect of Morphosyntactic Correctness (F (1,29) =

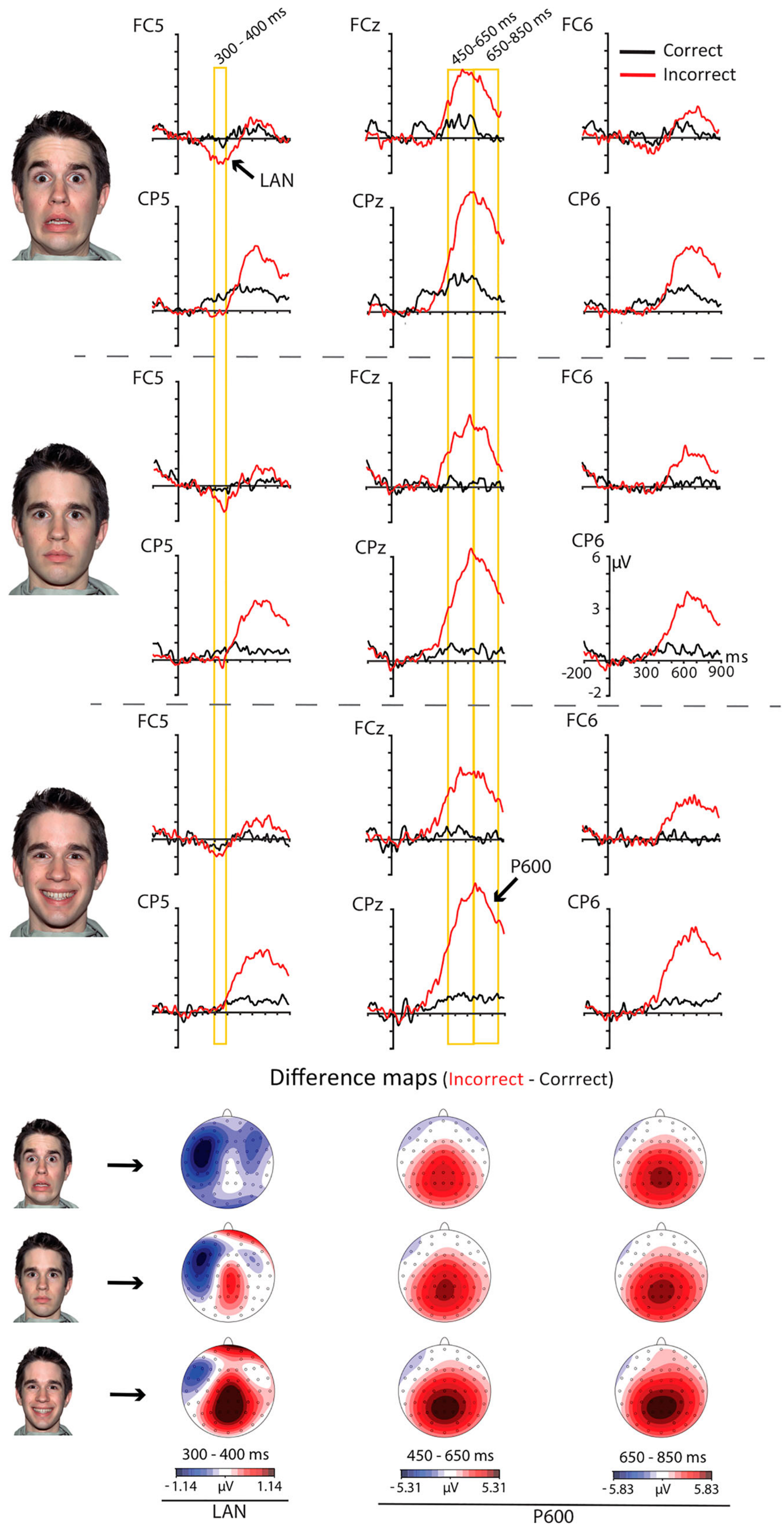

Figure 3. ERP waveforms for correct words and morphosyntactic violations. The topographies represent the difference maps for the LAN and P600 effects on each Emotional Expression.

68.1; $p < .001$; $\eta^2 = .06$; $\pi = 1$); participants responded significantly faster to incorrect than to correct sentences ($M = 363.14$ vs. 403.78 ms). In contrast, the main effect of Emotional Expression (F (2, 58) = 0.36; $p = .7$; $\eta^2 = .00$; $\pi = .11$) and its interaction with Morphosyntactic Correctness (F (2, 58) = 0.36; $p = .7$; $\eta^2 = .00$; $\pi = .16$) were not significant.

Figure 3 shows grand average ERPs to morphosyntactically correct and incorrect target words for each emotional facial expression. The ANOVA in the LAN interval (250–400 ms) confirmed a significant main effect of Morphosyntactic Correctness (F (1, 29) = 10.33; $p = .003$; $\eta^2 = .26$; $\pi = .87$). Neither the main effect of Emotional Expression (F (2,58) = .092; $p = .91$; $\eta^2 = .00$; $\pi = .06$), nor it's interaction with Morphosyntactic Correctness (F (2, 58) = 1.97; $p = .15$; $\eta^2 = .06$; $\pi = .39$) was statistically significant.

For the P600, ANOVAs for each time window revealed a strong main effect of Morphosyntactic Correctness (450–650 ms: F (1,29) = 51.62; $p < .001$; $\eta^2 = .64$; $\pi = 1$; 650–850 ms: F (1,29) = 133.97 $p < .001$; $\eta^2 = .82$; $\pi = 1$). Importantly, the ANOVA computed in the first P600 time window (450–650 ms) showed a significant interaction of Morphosyntactic Correctness by Emotional Expression (F (1, 29) = 3.72; $p = .03$; $\eta^2 = .114$; $\pi = .66$) (Figure 4, A). Post-hoc pairwise comparisons revealed that the P600 effect – incorrect vs. correct – was significant in all three emotion conditions (neutral: $\Delta = 3.61$ µV, $p < .001$; happy: $\Delta = 4.54$ µV, $p < .001$; fearful: $\Delta = 3.28$ µV, $p < .001$). The analyses also revealed that the P600 effect was significantly larger in the happy condition relative to the neutral (F (1, 29) = 4.6; $p = .04$; $\eta^2 = .14$; $\pi = .55$) and relative to the fearful condition (F (1, 29) = 5.92; $p = .02$; $\eta^2 = .17$; $\pi = .65$) (Figure 4). In contrast, the fearful and neutral conditions did not differ significantly (F (1, 29) = 0.46; $p = .4$; $\eta^2 = .02$; $\pi = .1$). Pairwise comparisons between emotions were also performed separately for correct and incorrect sentences. Analyses within correct sentences (Figure 4, B) evinced significant differences between the fearful speaker condition as compared to both neutral ($\Delta = 0.97$ µV, $p = .006$) and happy expressions ($\Delta = 0.85$ µV, $p = .05$). No significant differences were found between neutral and happy conditions ($\Delta = 0.119$ µV, $p = 1$). In contrast, analyses within incorrect sentences (Figure 4, C) only revealed a significant difference between neutral and happy trials – showing happy the largest P600 – ($\Delta = 1.05$ µV, $p = .01$), but neither between neutral and fearful ($\Delta = .664$ µV, $p = .19$) nor between the happy and fearful conditions ($\Delta = 0.41$ µV, $p < .76$). In the second P600 window (650–850 ms) the interaction of Morphosyntactic Correctness by Emotional Expression was not significant (F (1, 29) = 1.55; $p = .22$; $\eta^2 = 0.5$; $\pi = .31$).

The main effect of Emotional Expression was significant in both P600 time windows (450–650 ms: F (2, 58) = 7.36; $p = .001$; $\eta^2 = .20$; $\pi = .93$; 650–850 ms: F (2, 58) = 4.77; $p = .012$; $\eta^2 = .14$; $\pi = .77$). Post-hoc pairwise comparisons were performed to disentangle the main effect of emotion. First, the comparison of fearful vs. neutral emotional expressions yielded significant effects in both time windows (450–650 ms: $\Delta = 0.81$ µV, $p = .001$; 650–850 ms: $\Delta = 0.6$ µV, $p = .04$) due to the morphosyntactically correct condition. Second, the comparison of neutral and happy emotional expressions was a trend between 450 and 650 ms ($\Delta = 0.58$ µV, $p = .052$), and significant between 650 and 850 ms ($\Delta = 0.74$ µV, $p = .03$), related to a larger amplitude of the happy condition in the incorrect sentences. The comparison between fearful and happy conditions was not significant (all *ps* > .99). A visual inspection of the ERPs (Figure 5) showed positivity with centro-parietal distribution. Considering the present evidence, this main effect of Emotional Expression does not appear to be a genuine emotional effect, but a differential modulation of the P600 as a function of the emotional condition. In other words, correct sentences were boosted by the presence of a fearful speaker face, while incorrect sentences were boosted by happy faces. Moreover, this interpretation is coherent with an absence of emotion main effects in Study 1A.

Summarising, in this sub-study the LAN effect was not significantly modulated by affective visual stimuli. In turn, happy facial expressions evinced the strongest effect in the first half of the P600. Taken together, these findings indicate a differential pattern of language processing when parsing morphosyntactic anomalies as a function of the emotional valence of the speaker's face. In particular, seeing happy speaker's faces may engage heuristic processing in coherence with previous reports (Verhees et al., 2015; Vissers et al., 2010). Results are also in line with studies that manipulated emotion within the critical words (e.g. Martín-Loeches et al., 2012).

4. General discussion

The purpose of this study was to investigate language comprehension in face-to-face affective contexts. Particularly, we simulated a social-communicative context to investigate the effects of presenting a picture of the emotional facial expression of a speaker on the semantic and morphosyntactic processing of natural speech.

The most prominent results were found in Study 1B (syntactic domain), of a larger morphosyntactic P600 effect in the happy as compared to neutral and fearful speaker face conditions, which is in line with our

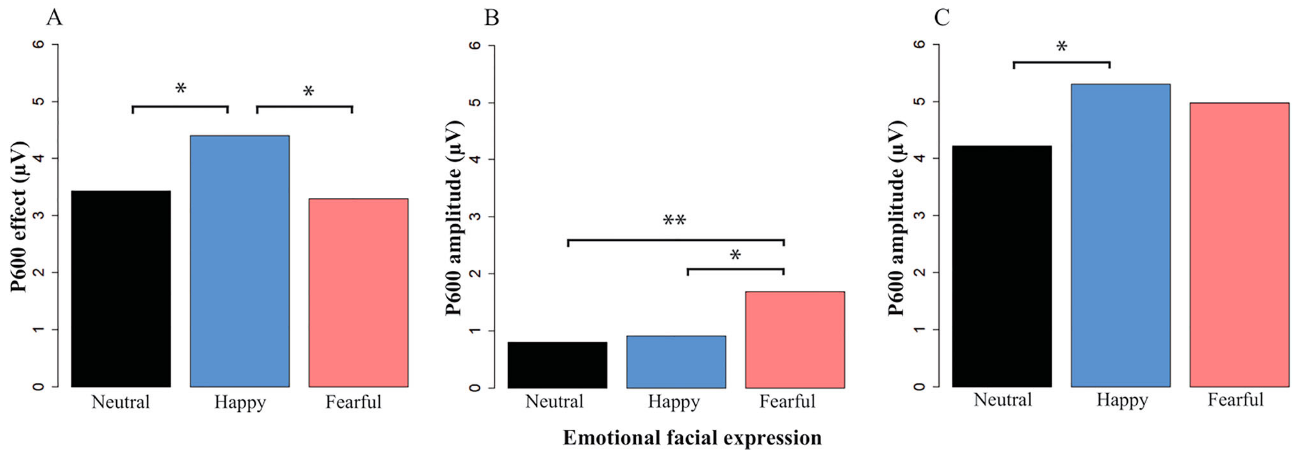

Figure 4. Bar graphs of the mean P600 effects (incorrect minus correct) (a), and the P600 amplitudes within correct sentences (b) and within incorrect sentences (c), on each emotional expression. The three bar graphs correspond to the 450–650 time window at P600 ROI, where the interaction Morphosyntactic Correctness by Emotional Expression was significant. $^*p \leq .05$, $^{**}p \leq .01$.

hypothesis. However, the fearful condition did not yield a smaller P600 effect, as predicted from other studies using visual stimuli – instead of verbal material – conveying emotional information (Verhees et al., 2015; Vissers et al., 2010). This is in line with Van Berkum et al. (2013), who found an earlier onset of the P600 in the happy condition related to an anticipation of the processing costs. An interesting finding related to this P600 interaction effect is that incorrect and correct sentences were differently affected by each facial expression. Specifically, correct sentences yielded larger amplitudes when accompanied by a fearful expression compared to the neutral and happy conditions. However, incorrect sentences in the happy condition showed a larger P600 component than in the neutral condition. Considering these results, the reanalysis of morphosyntactic errors seems to be prioritised over the negative emotional information received from the speaker's facial expression. Thus, when participants listen to incorrect sentences that hamper comprehension, the linguistic processing is not affected by the negative visual information. Otherwise, when participants listen to correct sentences and language comprehension is not constrained, an emotion effect appears. Curiously, this was not the case for the positive emotion. In this case, seeing the happy speaker expression only modulated the processing of incorrect sentences, increasing the resources invested in the reanalysis of the morphosyntactic errors, which relates to the largest P600 effect, as predicted in our hypothesis.

Differences in information processing styles may explain the P600 findings. Hence, the P600 effect to morphosyntactic violations was expected to increase in the happy condition probably because positive emotions trigger a heuristic, less demanding processing style (Bless & Schwarz, 1999; Gasper & Clore, 2002; Isen, 2001). A heuristic linguistic processing does not consider all the information available to complete syntactic parsing, and therefore it is necessary to invest more resources in the reanalysis of the sentences. However, we did not observe the expected significant decrement of the LAN effect to happy speaker faces, nor a significant boost of the effect in the fearful condition, in line with Díaz-Lago et al. (2015), Fraga et al. (2017) and Padrón et al. (2020). Even though, a visual inspection of the ERPs (Figure 3) suggests a prominent LAN component in the fearful condition and a barely visible one in the happy condition. Considering both the short duration and the small magnitude of the LAN component, it is possible that the natural auditory presentation of the sentences and the manual location of the triggers on each word augmented the variability among trials and the noise of the EEG signal, which hampered the emergence of significant differences between emotions. Jittering of ERPs is a typical problem related to spoken sentences because of the incremental stimulus presentation and the use of target words with different length (Alday et al., 2017). Previous research in morphosyntactic processing has shown a continuum between individuals showing a negative ERP pattern (LAN) and those showing a positive pattern (P600) (e.g. Caffarra et al., 2019; Fraga et al., 2021; Tanner & Van Hell, 2014). Our study was not designed to investigate such individual processing differences, but they might affect the biphasic LAN-P600 result. This should be considered in future studies.

A reduction of the P600, – usually accompanied by an increase of the LAN –, is also a pattern that has been reported in individuals with good compared to poor linguistic comprehension and better working memory capacity (King & Kutas, 1995; Vos et al., 2001; Tanner &

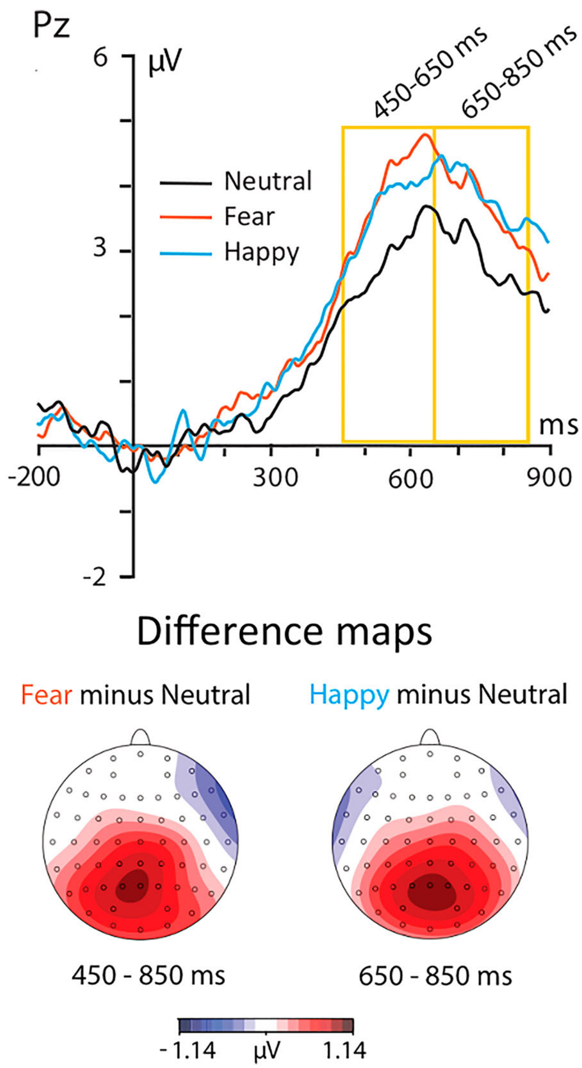

Figure 5. ERPs of critical words on each emotional expression (neutral, fearful, happy). Correct and incorrect words are collapsed. Only the Pz electrode is plotted. The difference maps represent the topographies resulting from the comparison of fear and happy conditions to control (neutral).

Van Hell, 2014). Therefore, seeing the speaker with a happy face may have triggered a – relatively inefficient – heuristic processing strategy compared to a fearful speaker. This may have led to a shift to more analytic processing, increasing the efforts invested in the comprehension of the sentence (such an explanation based on the efficiency of processing is in line with previous linguistic ERP studies, e.g. Espuny et al., 2018). However, this only applied to correct sentences. Maybe, when the speaker showed a fearful expression, participants analysed these sentences more thoroughly than when being presented with neutral and happy expressions, acting more diligently. On the contrary, incorrect sentences did not require extra scrutiny because it was clear that they were deficient. An alternative interpretation to consider is that fearful faces lead to a closer scrutiny of any sentence, leading to a larger effect in the correct sentences compared to the other emotional expressions, but not in the incorrect sentences because of a ceiling effect. Lastly, considering that in the present study language comprehension was situated in an affective (simulated) face-to-face context, the P600 boost after happy emotional expressions might be also related to social-affective processes. During face evaluation, humans obtain an impression of other individuals (Safra et al., 2020). Thus, happy faces increase social motivation to approach, and stimulate communication in social contexts (Nikitin & Freund, 2019). Therefore, such positive affect towards the speaker might have resulted in the higher-order processes indexed by the P600.

In Study 1B (semantic domain) neither the modulation of the N400 effect by the emotional facial expressions of the speaker, nor the behavioural results, were statistically significant. Specific visual differences in the scalp distribution of the N400 appeared between emotional facial expressions, but they were not supported by statistical analyses. This result is in line with previous studies that failed to find a modulation of the N400 effect by emotional information unrelated to sentence content, neither manipulating emotional valence in the critical words (Martín-Loeches et al., 2012) nor presenting emotion-laden language before the sentences. Accordingly, the N400 does not seem to be affected by social-emotional information unrelated to the semantic congruence of the critical word, and this is so irrespective of the moment when the affective stimulus is processed (preceding or within the sentence), as well as of the type of emotional stimuli employed (linguistic, non-linguistic), even if it was expected that faces might increase the relevance of the context. This is in consonance with the results of Hernández-Gutiérrez et al. (2021) who investigated whether the dynamic features of the speaker's face could facilitate semantic processing of speech. Participants listened to spoken sentences while watching either a video or a still picture of the speaker's face. The N400 component to unexpected sentences was not significantly different between both visual conditions, although a dynamic video is a richer communicative context than a static image, and more similar to a natural interpersonal situation. Therefore, when semantic comprehension is demanding, the cognitive system may prioritise language comprehension over visual cues (Hernández-Gutiérrez et al., 2021).

Regarding possible limitations of our study, firstly, one might consider that coupling the speaker's emotional facial expression with certain sentences could be incongruent by itself. In other words, the visual stimuli could add positive or negative valence to the communicative context that does not correspond with the neutral content of the sentence. If this were the case, congruent neutral sentences uttered by happy and fearful speakers would generate a larger N400 compared to the same sentences uttered by speakers with neutral expression. However, we did not find such a difference. In addition, correct words in emotional conditions did not seem to exhibit larger N400 components. Even though, considering the multi-modal nature of language processing, which is usually based on congruent information, the experimental manipulation may be more ecological and stronger if congruent. Follow-up investigations might compare emotional sentences spoken in emotional prosody and preceded by emotional faces with all neutral conditions. Secondly, an intrinsic limitation to using natural speech compared to visual stimuli is the incremental stimulus presentation, differences in length of target words, and jittering of ERPs (Alday et al., 2017). Even though it was possible to observe satisfying ERP components to our experimental manipulations, allowing to investigate language comprehension within an affective simulated face-to-face context. However, is necessary to point out that differences in the LAN effect between speakers' facial expressions may not have reached statistical significance because of this reason, since the use of auditory stimuli resulted in a noisier EEG, adding more variability to the data. Finally, follow-up studies may benefit from including larger sample sizes.

In conclusion, we have situated the participants in a simulated social context to examine how the neural basis of language comprehension can be affected by an emotion-laden stimulus that is especially relevant for the communicative process, namely the speaker's face. Ultimately, our results support the claim that processing a speaker's emotional facial expression impacts speech processing in the syntactic domain. Hence, the P600 effect is boosted when facing a happy speaker, probably related to reanalysis or reprocessing costs, in line with a heuristic type of processing with positive emotions. The modulation of this component was found even in the absence of an emotion-related task, and in a situation in which the emotional information was irrelevant to the main linguistic task. This finding adds new information on how social situational contexts, where language normally occurs, constrain its neural and cognitive mechanisms.

Acknowledgements

This research was supported by the Spanish Ministerio de Economía y Competitividad [grant codes PSI2013-43107-P and PSI2017-82357-P] (MINECO, Programa Estatal de Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento y Proyectos de I + D).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Ministry of Economy and Competitiveness: [Grant Number PSI2013-43107-P,PSI2017-82357-P].

ORCID

David Hernández-Gutiérrez http://orcid.org/0000-0003-3723-1075
Francisco Muñoz http://orcid.org/0000-0001-9241-3838
Zahra Khosrowtaj http://orcid.org/0000-0001-5327-9656
Werner Sommer http://orcid.org/0000-0001-5266-3445
Laura Jiménez-Ortega http://orcid.org/0000-0001-8002-5563
José Sánchez-García http://orcid.org/0000-0002-0277-2157
Pilar Casado http://orcid.org/0000-0002-3991-4155
Sabela Fondevila http://orcid.org/0000-0003-4004-2320
Javier Espuny http://orcid.org/0000-0001-5438-4183
Manuel Martín-Loeches http://orcid.org/0000-0002-3487-8423
Rasha Abdel Rahman http://orcid.org/0000-0002-8438-1570

References

Alday, P. M., Schlesewsky, M., & Bornkessel-Schlesewsky, I. (2017). Electrophysiology reveals the neural dynamics of naturalistic auditory language processing: Event-related potentials reflect continuous model updates. *eNeuro*, *4*(6), ENEURO. https://doi.org/10.1523/ENEURO.0311-16.2017

Barraclough*, N. E., Xiao*, D., Baker, C. I., Oram, M. W., & Perrett, D. I. (2005). Integration of visual and auditory information by superior temporal sulcus neurons responsive to the sight of actions. *Journal of Cognitive Neuroscience*, *17*(3), 377–391. 1972. https://doi.org/10.1162/0898929053279586

Binder, J. R., Frost, J. A., Hammeke, T. A., Cox, R. W., Rao, S. M., & Prieto, T. (1997). Human brain language areas identified by functional magnetic resonance imaging. *Journal of Neuroscience*, *17*(1), 353–362. https://doi.org/10.1523/JNEUROSCI.17-01-00353.1997

Blackett, D. S., Harnish, S. M., Lundine, J. P., Zezinka, A., & Healy, E. W. (2017). The effect of stimulus valence on lexical retrieval in younger and older adults. *Journal of Speech, Language, and Hearing Research*, *60*(7), 2081–2089. https://doi.org/10.1044/2017_JSLHR-L-16-0268

Bless, H., & Schwarz, N. (1999). Sufficient and necessary conditions in dual process models: The case of mood and information processing. In S. Chaiken & Y. Trope (Eds.), *Dual-process theories in social psychology* (pp. 423–440). Guilford Press.

Caffarra, S., Mendoza, M., & Davidson, D. (2019). Is the LAN effect in morphosyntactic processing an ERP artifact? *Brain and Language*, *191*, 9–16. https://doi.org/10.1016/j.bandl.2019.01.003

Chwilla, D. J., Virgillito, D., & Vissers, C. T. W. (2011). The relationship of language and emotion: N400 support for an embodied view of language comprehension. *Journal of Cognitive Neuroscience*, *23*(9), 2400–2414. https://doi.org/10.1162/jocn.2010.21578

Crossfield, E., & Damian, M. F. (2021). The role of valence in word processing: Evidence from lexical decision and emotional Stroop tasks. *Acta Psychologica*, *218*, 103359. https://doi.org/10.1016/j.actpsy.2021.103359

Díaz-Lago, M., Fraga, I., & Acuña-Fariña, C. (2015). Time course of gender agreement violations containing emotional words. *Journal of Neurolinguistics*, *36*, 79–93. https://doi.org/10.1016/j.jneuroling.2015.07.001

Engell, A. D., & Haxby, J. V. (2007). Facial expression and gaze-direction in human superior temporal sulcus. *Neuropsychologia*, *45*(14), 3234–3241. https://doi.org/10.1016/j.neuropsychologia.2007.06.022

Espuny, J., Jiménez-Ortega, L., Hernández-Gutiérrez, D., Muñoz, F., Fondevila, S., Casado, P., & Martín-Loeches, M. (2018). Isolating the effects of word's emotional valence on subsequent morphosyntactic processing: An event-related brain potentials study. *Frontiers in Psychology*, *9*, 2291. https://doi.org/10.3389/fpsyg.2018.02291

Federmeier, K. D., Kirson, D. A., Moreno, E. M., & Kutas, M. (2001). Effects of transient, mild mood states on semantic memory organization and use: An event-related potential investigation in humans. *Neuroscience Letters*, *305*(3), 149–152. https://doi.org/10.1016/s0304-3940(01)01843-2

Fraga, I., Padrón, I., Acuña-Fariña, C., & Díaz-Lago, M. (2017). Processing gender agreement and word emotionality: New electrophysiological and behavioural evidence. *Journal of Neurolinguistics*, *44*, 203–222. https://doi.org/10.1016/j.jneuroling.2017.06.002

Fraga, I., Padrón, I., & Hinojosa, J. A. (2021). Negative valence effects on the processing of agreement dependencies are mediated by ERP individual differences in morphosyntactic processing. *Language, Cognition and Neuroscience*, *36*(10), 1215–1233. https://doi.org/10.1080/23273798.2021.1922725

Friederici, A. D. (2011). The brain basis of language processing: From structure to function. *Physiological Reviews*, *91*(4), 1357–1392. https://doi.org/10.1152/physrev.00006.2011

Friederici, A. D., Bahlmann, J., Heim, S., Schubotz, R. I., & Anwander, A. (2006). The brain differentiates human and non-human grammars: Functional localization and structural connectivity. *Proceedings of the National Academy of Sciences*, *103*(7), 2458–2463. https://doi.org/10.1073/pnas.0509389103

Friederici, A. D., Makuuchi, M., & Bahlmann, J. (2009). The role of the posterior superior temporal cortex in sentence comprehension. *Neuroreport*, *20*(6), 563–568. https://doi.org/10.1097/WNR.0b013e3283297dee

Gasper, K., & Clore, G. L. (2002). Attending to the big picture: Mood and global versus local processing of visual information. *Psychological Science*, *13*(1), 34–40. https://doi.org/10.1111/1467-9280.00406

Gibson, E., Futrell, R., Piantadosi, S. P., Dautriche, I., Mahowald, K., Bergen, L., & Levy, R. (2019). How efficiency shapes human language. *Trends in Cognitive Sciences*, *23*(5), 389–407. https://doi.org/10.1016/j.tics.2019.02.003

Hernández-Gutiérrez, D., Muñoz, F., Sánchez-García, J., Sommer, W., Abdel Rahman, R., Casado, P., Jiménez-Ortega, I., Espuny, J., Fondevila, S., & Martín-Loeches, M. (2021). Situating language in a minimal social context: How seeing a picture of the speaker's face affects language comprehension. *Social Cognitive and Affective Neuroscience*, *16*(5), 502–511. https://doi.org/10.1093/scan/nsab009

Hernández-Gutiérrez, D., Rahman, R. A., Martín-Loeches, M., Muñoz, F., Schacht, A., & Sommer, W. (2018). Does dynamic information about the speaker's face contribute to semantic speech processing? ERP evidence. *Cortex*, *104*, 12–25. https://doi.org/10.1016/j.cortex.2018.03.031

Hinojosa, J. A., Moreno, E. M., & Ferré, P. (2020). Affective neurolinguistics: Towards a framework for reconciling language and emotion. *Language, Cognition and Neuroscience*, *35*(7), 813–839. https://doi.org/10.1080/23273798.2019.1620957

Holt, D. J., Lynn, S. K., & Kuperberg, G. R. (2009). Neurophysiological correlates of comprehending emotional meaning in context. *Journal of Cognitive Neuroscience*, *21*(11), 2245–2262. https://doi.org/10.1162/jocn.2008.21151

Isen, A. M. (2001). An influence of positive affect on decision making in complex situations: Theoretical issues with practical implications. *Journal of Consumer Psychology*, *11*(2), 75–85. https://doi.org/10.1207/S15327663JCP1102_01

Jiménez-Ortega, L., Espuny, J., Herreros de Tejada, P., Vargas-Rivero, C., & & Martín-Loeches, M. (2017). Subliminal emotional words impact syntactic processing: Evidence from performance and event-related brain potentials. *Frontiers in Human Neuroscience*, *11*, 192. https://doi.org/10.3389/fnhum.2017.0019

Jiménez-Ortega, L., Martín-Loeches, M., Casado, P., Sel, A., Fondevila, S., Herreros de Tejada, P., Schacht, A., & & Sommer, W. (2012). How the emotional content of discourse affects language comprehension. *PLoS One*, *7*(3), e33718. https://doi.org/10.1371/journal.pone.0033718

King, J. W., & Kutas, M. (1995). Who did what and when? Using word-and clauselevel ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience*, *7*(3), 376–395.

Kousta, S. T., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition*, *112*(3), 473–481. https://doi.org/10.1016/j.cognition.2009.06.007

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology*, *62*(1), 621–647. https://doi.org/10.1146/annurev.psych.093008.131123

Martín-Loeches, M., Fernández, A., Schacht, A., Sommer, W., Casado, P., Jiménez-Ortega, L., & Fondevila, S. (2012). The influence of emotional words on sentence processing: Electrophysiological and behavioral evidence. *Neuropsychologia*, *50*(14), 3262–3272. https://doi.org/10.1016/j.neuropsychologia.2012.09.010

Molinaro, N., Barber, H. A., & Carreiras, M. (2011). Grammatical agreement processing in Reading: ERP findings and future directions. *Cortex*, *47*(8), 908–930. https://doi.org/10.1016/j.cortex.2011.02.019

Münster, K., & Knoeferle, P. (2018). Extending situated language comprehension (accounts) with speaker and comprehender characteristics: Toward socially situated interpretation. *Frontiers in Psychology*, *8*(2267), 1–12. https://doi.org/10.3389/fpsyg.2017.02267

Nikitin, J., & Freund, A. M. (2019). The motivational power of the happy face. *Brain Sciences*, *9*(1), 1–18. https://doi.org/10.3390/brainsci9010006

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Olson, I. R., McCoy, D., Klobusicky, E., & Ross, L. A. (2013). Social cognition and the anterior temporal lobes: A review and theoretical framework. *Social Cognitive and Affective Neuroscience*, *8*(2), 123–133. https://doi.org/10.1093/scan/nss119

Padrón, I., Fraga, I., & Acuña-Fariña, C. (2020). Processing gender agreement errors in pleasant and unpleasant words: An ERP study at the sentence level. *Neuroscience Letters*, *714*, 134538. https://doi.org/10.1016/j.neulet.2019.134538

Patterson, K., & Lambon Ralph, M. A. (2016). The Hub-and-Spoke hypothesis of semantic memory. In G. Hickok, & S. L. Small (Eds.), *Neurobiology of language* (pp. 765–775). Academic. https://doi.org/10.1016/B978-0-12-407794-2.00061-4

Payne, B. R., Lee, C. L., & Federmeier, K. D. (2015). Revisiting the incremental effects of context on word processing: Evidence from single-word event-related brain potentials. *Psychophysiology*, *52*(11), 1456–1469. https://doi.org/10.1111/psyp.12515

Safra, L., Baumard, N., Wyart, V., & Chevallier, C. (2020). Social motivation is associated with increased weight granted to cooperation-related impressions in face evaluation tasks. *PloS One*, *15*(4), e0230011. https://doi.org/10.1371/journal.pone.0230011

Schöne, B., Köster, M., & Gruber, T. (2018). Coherence in general and personal semantic knowledge: Functional differences of the posterior and centroparietal N400 ERP component. *Experimental Brain Research*, *236*(10), 2649–2660. https://doi.org/10.1007/s00221-018-5324-1

Scott, G. G., O'Donnell, P. J., & Sereno, S. C. (2012). Emotion words affect eye fixations during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(3), 783. https://doi.org/10.1037/a0027209

Somerville, L. H., Fani, N., & McClure-Tone, E. B. (2011). Behavioral and neural representation of emotional facial expressions across the lifespan. *Developmental Neuropsychology*, *36*(4), 408–428. https://doi.org/10.1080/87565641.2010.549865

Tanner, D., & Van Hell, J. G. (2014). ERPs reveal individual differences in morphosyntactic processing. *Neuropsychologia*, *56*, 289–301. https://doi.org/10.1016/j.neuropsychologia.2014.02.002

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. https://doi.org/10.1016/j.psychres.2008.05.006

Van Berkum, J. J., De Goede, D., Van Alphen, P., Mulder, E., & Kerstholt, J. H. (2013). How robust is the language architecture? The case of mood. *Frontiers in Psychology*, *4*, 505. https://doi.org/10.3389/fpsyg.2013.00505

Van Petten, C. (2014). Examining the N400 semantic context effect item-by-item: Relationship to corpus-based measures of word co-occurrence. *International Journal of Psychophysiology*, *94*(3), 407–419. https://doi.org/10.1016/j.ijpsycho.2014.10.012

Verhees, M. W., Chwilla, D. J., Tromp, J., & Vissers, C. T. (2015). Contributions of emotional state and attention to the processing of syntactic agreement errors: Evidence from P600. *Frontiers in Psychology*, *6*, 388. https://doi.org/10.3389/fpsyg.2015.00388

Vissers, C. T. W., Virgillito, M., Fitzgerald, D., Speckens, D. A., Tendolkar, A. E., van Oostrom, I., & Chwilla, I., & J, D. (2010). The influence of mood on the processing of syntactic anomalies: Evidence from P600. *Neuropsychologia*, *48*(12), 3521–3531. https://doi.org/10.1016/j.neuropsychologia.2010.08.001

Vos, S. H., Gunter, T. C., Kolk, H. H., & Mulder, G. (2001). Working memory constraints on syntactic processing: An electrophysiological investigation. *Psychophysiology*, *38*(1), 41–63.

Xu, J., Abdel Rahman, R., & Sommer, W. (2020). Perceived language competence modulates criteria for speech error processing: Evidence from event-related potentials. *Language, Cognition and Neuroscience*, *35*(6), 752–765. https://doi.org/10.1080/23273798.2018.1562558

Xu, J., Abdel Rahman, R., & Sommer, W. (2021a). Sequential adaptation effects reveal proactive control in processing spoken sentences: Evidence from event-related potentials. *Brain and Language*, *214*, 104904. https://doi.org/10.1016/j.bandl.2020.104904

Xu, J., Abdel Rahman, R., & Sommer, W. (2021b). Who speaks next? Adaptations to speaker identity in processing spoken sentences. *Psychophysiology*, e13948. https://doi.org/10.1111/psyp.13948

Yan, M., & Sommer, W. (2015). Parafoveal-on-foveal effects of emotional word semantics in Reading Chinese sentences: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(4), 1237. https://doi.org/10.1037/xlm0000095.supp

Yan, M., & Sommer, W. (2019). The effects of emotional significance of foveal words on the parafoveal processing of N + 2 words in reading Chinese sentences. *Reading and Writing*, *32*(5), 1243–1256. https://doi.org/10.1007/s11145-018-9914-x