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Research Report

Language comprehension in the social brain: Electrophysiological brain signals of social presence effects during syntactic and semantic sentence processing



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ABSTRACT

Although, evolutionarily, language emerged predominantly for social purposes, much has yet to be uncovered regarding how language processing is affected by social context. Social presence research studies the ways in which the presence of a conspecific affects processing, but has yet to be thoroughly applied to language processes. The principal aim of this study was to see how syntactic and semantic language processing might be subject to mere social presence effects by studying Event-Related brain Potentials (ERP). In a sentence correctness task, participants read sentences with a semantic or syntactic anomaly while being either alone or in the mere presence of a confederate. Compared to the alone condition, the presence condition was associated with an enhanced N400 component and a more centro-posterior LAN component (interpreted as an N400). The results seem to imply a boosting of heuristic language processing strategies, proper of lexico-semantic operations, which actually entails a shift in the strategy to process morphosyntactic violations, typically based on algorithmic or rule-based strategies. The effects cannot be related to increased arousal levels. The apparent enhancement of the activity in the precuneus while in presence of another person suggests that the effects conceivably relate to social cognitive and attentional factors. The present results suggest that understanding language comprehension would not be complete without considering the impact of social presence effects, inherent to the most natural and fundamental communicative scenarios.

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1. Introduction

Although it is known that social information is taken into account during language processes (Niedzielski, 1999; Statum Casasanto, 2008), the ways in which social context impacts language processing are still being uncovered. The present study aims at exploring the effects of mere social presence on semantic and syntactic language comprehension.

Social facilitation theory focuses on the changes that occur in an individual's performance when that person performs in the presence of others vs alone (Aiello & Douthitt, 2001). Social presence effects are often attributed to increased drive or physiological arousal, shifts in the allocation of attentional resources or increased attentional focus, social distraction, modelling co-actors mental states, as well as fear of social evaluation (see Guerin, 1993; Aiello & Douthitt, 2001; Belleter, Normand, & Huguet, 2019 for reviews). Additionally, the task, the type of presence, and relationship between the participant and the "other" may play important roles in moderating said effects (Aiello & Douthitt, 2001; He, Lever, & Humphreys, 2011), leading to a long-lasting debate as to whether mere presence is truly enough to elicit social facilitation effects (Allport, 1924; Chapman, 1974; Platania & Moran, 2001; Schmitt, Gilovich, Goore, & Joseph, 1986) or not (e.g. Cottrell, Wack, Sekerak, & Rittle, 1968; Guerin, 1993), and whether task complexity mediates these effects (e.g. Baron, 1986; Zajonc, 1965, 1980). Social facilitation effects have been reported as affecting various cognitive processes, such as learning and memory (Hartwick & Nagao, 1990; Higgs & Joseph, 1971). However, no one theory has been able to effectively and comprehensively account for social presence effects, perhaps in part due to the wide variety of behavioral effects that have been reported (see Aiello & Douthitt, 2001; Guerin, 1993).

Recent approaches have focused not only on behavior but have employed brain-imaging techniques to better understand the underlying processes involved in social presence effects. Researchers have documented increased activity in regions involved in reward outcome valuation, social cognition and motivation (Chib, Adachi, & O'Doherty, 2018), and in networks related to mentalizing, when participants were being observed compared to when alone (Müller-Pinzler et al., 2015; Yoshie, Nagai, Critchley, & Harrison, 2016), even though in some cases they were not performing a task or being evaluated (Somerville, 2013). These findings were also accompanied by improved performance in the social condition. Remarkably, these effects are not exclusively human; studies involving rhesus macaques have found improved performance on reward-based visuomotor tasks when in front of a co-actor (Reynaud, Guedj, Hadj-Bouziane, Meunier, & Monfardini, 2015), differential involvement of neurons in the prefrontal cortex as a function of social condition (Demolliens, Isbaine, Takerkart, Huguet, & Boussaoud, 2017), as well as enhanced metabolic brain activity in the attention fronto-parietal network associated with the social presence condition (Monfardini et al., 2016).

Under the basic assumption that humans are a social species which have an increased communication level, and that language developed as a social and cultural tool to facilitate this interaction (Dunbar, 2017; Pinker & Jackendoff, 2005;

Tomasello, Call, & Hare, 2003), it is plausible that the presence of another person could noticeably impact language processing. Indeed, social information and social context appear of the highest relevance in language processes (Bara, Enrici, & Adenzato, 2016; Barr & Keysar, 2006; Brown-Schmidt & Heller, 2018; Hasson, Egidi, Marelli, & Willems, 2018; Pulvermüller & Fadiga, 2016). The present paper explores whether the mere presence of another person may influence semantic and syntactic language processing, as this has been under-investigated to date.

Given its high (msec) temporal resolution, Event-Related brain Potentials (ERP) is a technique suitable to study psycholinguistic processes as they unfold over time. This has been particularly proved for semantic and syntactic sentence comprehension, as indeed a number of ERP components have been established as reflecting these processes. The N400 component, a negative centro-parietal fluctuation around 400 ms, is understood as a fundamental indicator of semantic processing (Kutas & Federmeier, 2011), likely representing the amount of resources needed to integrate word meaning into a current context (Hagoort, Hald, Bastiaansen, & Petersson, 2004). The earlier, often left-lateralized anterior negativity (LAN) between 100 and 500 ms is associated with first-pass parsing (Hahne & Friederici, 1999) and has been reported primarily for grammatical anomalies including morphosyntactic violations (e.g. number, gender or subject-verb violations), and correct but strange grammatical structures (Steinhauer & Connolly, 2008). The later (500–1000 ms) centro-parietal positive component (P600), a more general marker for structural processing, reflects a later-stage reanalysis and reintegration (Steinhauer & Connolly, 2008; Molarino, Barber, & Carreiras, 2011), while the "semantic P600", when found, has been also linked to the assessment of incoming information to update the mental model (Burkhardt, 2007).

As reviewed in Friederici (2017), the LAN is most probably originated in area BA44 of the left inferior frontal gyrus (IFG), which, together with the posterior superior temporal sulcus (STS) underlie syntactic processing (Matchin, Hammerly, & Lau, 2017). On the other hand, semantics is predominantly processed rightly thereafter in left BA45 and BA47 (in the IFG), as well as in the left anterior temporal lobe (ATL), mainly comprising BA38, but also part of BA21 and BA22 (Pylkkanen, 2019; Schell, Zaccarella, & Friederici, 2017); all of them would be presumably contributing to the N400 (Ardila, Bernal, & Rosselli, 2017; Friederici, 2011; Matchin et al., 2017; Pylkkanen, 2019; Schell et al., 2017). Later, the P600 emerges probably originated in the angular gyrus (AG) and the posterior superior temporal gyrus (STG) (Friederici, 2017; Schell et al., 2017).

Only a few previous studies have used ERP to study social presence effects on language processing. Employing a joint comprehension task, several studies (Rueschemeyer, Gardner, & Stoner, 2014; Westley, Kohút & Resuchemeyer, 2017; Jouravlev et al., 2019) looked at how participants' knowledge about another listener's understanding could affect their own comprehension of semantically plausible or implausible sentences, when participants were given more information about the plausibility of a sentence than the confederate. Whereas no N400 was elicited for the participants in isolation, for those in the joint condition an N400 effect occurred in response to

sentences that were correct for the participant but incorrect for the co-listener, even when they were not instructed to reflect on the co-listener's perspective. This "social N400" effect demonstrates that people integrate the perspective of others during language comprehension (Jouravlev et al., 2019; Westley, Kohút, & Rueschemeyer, 2017). The effects of the mere presence of another person on syntax processing, on the other hand, remain unexplored. The possibility that syntactic processes are affected by the presence of others seems feasible, however. Against the traditional view that syntax is an encapsulated process (e.g., Fodor, 1983; Hauser, Chomsky, & Fitch, 2002), several studies have proven that it can be influenced by extra-linguistic variables (e.g., Jiménez-Ortega et al., 2012; Casado et al., 2018; 2020). Additionally, the mere presence of a conspecific has been seen to increase the activation of Brodmann's areas 45 and 46 (Monfardini, 2016), overlapping therefore with parts of Broca's area involved in syntactic as well as semantic processing (Friederici, 2017; Hagoort, 2005). In the same line, the posterior superior temporal sulcus is also a region concerned with both syntactic (e.g., Zaccarella, Meyer, Makuuchi, & Friederici, 2015) and social processing (e.g., Adolphs, 2009; Shultz, Lee, Pelphrey, & McCarthy, 2011).

The necessity to further study the effects of social presence on semantic and syntactic processes therefore seems granted, particularly if we want to understand language in depth, and its arrangement within the human cognitive machinery. The present study aimed to investigate whether social presence influences language processing in a violation-paradigm task involving morphosyntactic and semantic errors, focusing on a mere presence scenario (i.e., the co-present person is neither evaluating nor interacting with the participant). Predictions are not straightforward at this stage, given the variety of the proposed causes for social presence effects (i.e., from basic/general arousal activations to attentional or social cognitive variables). As reviewed above, this remains a debated subject and indeed several of these reasons may coexist. On the other hand, syntax and semantics are far from equivalent operations, as both relate to different cognitive strategies that might in turn be differentially affected by social presence factors. In this regard, while semantics is mostly a heuristic process, mostly based on free association knowledge mechanisms, syntax is a rule-based operation, highly algorithmic in nature (Martín-Loeches et al., 2009). As the task employed here is relatively simple, facilitative effects might be expected, and therefore a reduction of the ERP components LAN, N400 and/or P600 as a signal of less effort devoted to the corresponding linguistic processes (e.g., Hagoort, 2003) might also be expected. However, the interaction between the factors potentially involved in triggering social presence effects and the different nature of the linguistic processes explored here might complicate the picture, particularly considering the highly social character of language. Given the exploratory purpose of the present study, the bulk of possibly involved causes for the social presence effects will not be systematically manipulated. Yet, a measure of participants' arousal levels will be employed (skin conductance), which could shed some light on the possible contribution of this factor to our results.

2. Materials & methods

We report how we determined our sample size, all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study. To establish the sample size, we followed the recommendation offered by Larson and Carbine (2017), in addition effect size and power calculations are included for all analyses in the result section.

2.1. Participants

Twenty-eight female and two male ($n = 30$) Spanish-speaking University Students (mean age = 22.5, $SD = 2.7$) participated in the present study after giving informed consent according to the Declaration of Helsinki and with the approval of the ethics committee of the Complutense University. All participants had self-reported normal or corrected-to-normal vision, no history of neural or cognitive disorders, were not on psychiatric medications, and were all right-handed ($M = 78.6$, $SD = 21.58$), according to the Edinburgh Handedness Inventory (Oldfield, 1971). In order to be included, participants had to be native Spanish speakers, have no reading difficulties and have lived in Spain for at least five years prior to the study in order to be familiar with the vocabulary utilized in the language task.

2.2. Materials

The language material consisted of a total of 300 neutral experimental Spanish sentences plus fillers (100). The fillers were always correct sentences, while each experimental sentence was modified to form two types of incorrect sentences: those with a semantic violation, and those with a syntactic violation. Half of these sentences were used, without the complement, in a previous experiment (Jiménez-Ortega, Espuny, de Tejada, Vargas-Rivero, & Martín-Loeches, 2017) and the remaining sentences were generated using a similar pattern. Both short sentences (determinant-noun-adjective-verb-complement) and long sentences (determinant-noun-adjective-noun-preposition-complement) exemplified structures commonly used in Spanish (see Table 1 for examples). The fillers were also long and short sentences, with structures other than those used in the experimental sentences (sentences and Presentation® files can be found at <https://osf.io/bh3r3>).

The semantically anomalous sentences were constructed by interchanging either the adjective or the verb between the semantically acceptable sentences. This was performed in a pseudo-random manner, that is, substitutions were made randomly but if a given combination resulted semantically plausible, it was interchanged again. The acceptability of semantic anomalies was then calculated by comparing the number of hits on Google for the (semantically incorrect) pairing of a given noun followed by its paired adjective (e.g. "detective fluorescente" (*fluorescent detective*)) or verb (e.g. "detective tintinea" (*detective chinks*)), to the number of hits for the semantically correct word pairing (e.g. "detective listo" (*smart detective*); "detective investiga" (*detective investigates*)).

Table 1 – Types and examples of sentences used in the experimental procedure.

Short Sentences	Determinant	Noun	Adjective	Verb	Complement	
Correct	Los The	trenes trains	nocturnos <i>night (m.)</i>	llegan arrive	puntuales. punctually.	
Semantic Anomaly	Los The	trenes trains	persistentes persistent	llegan arrive	puntuales. punctually.	
Syntactic Anomaly (Gender)	Los The	trenes trains	nocturnas <i>night (f.)</i>	llegan arrive	puntuales. punctually.	
Long Sentences	Determinant	Noun	Adjective	Verb	Preposition	Complement
Correct	La The	noche <i>night</i>	serena <i>serene</i>	sitúa <i>situates (sg.)</i>	al <i>the</i>	explorador. <i>explorer.</i>
Semantic Anomaly	La The	noche <i>night</i>	serena <i>serene</i>	legisla <i>legislates</i>	al <i>the</i>	explorador. <i>explorer.</i>
Syntactic Anomaly (Plurality)	La The	noche <i>night</i>	serena <i>serene</i>	sitúan <i>situate (pl.)</i>	al <i>the</i>	explorador. <i>explorer.</i>

Note. Literal translations (noun-adjective order inverted) into English, where m., masculine; f., feminine; sg., singular; pl., plural. Bold words represent semantic or syntactic anomaly.

The average of hits for semantic violation pairings was 398 ($SD = 1068.09$), and was significantly lower than that of correct pairings, which was 62361 hits ($SD = 455539.93$; $t(298) = 2.354$, $p < .05$), justifying that the noun-adjective and noun-verb combinations used were quite common in the case of correct sentences, and rather uncommon in the case of sentences with semantic violations. Frequency, valence, and length of critical words were not counterbalanced, as they were used in all conditions. The semantic or syntactic anomaly could be presented in the adjective or in the verb. Syntactic violations in the adjective consisted of either a gender violation or a number violation, whereas they were number violations in the verb. Table 1 displays examples of the materials used.

In total, three different presentation sets of sentences were composed, containing different combinations of sentences and avoiding the repetition of an experimental sentence within a given set. They were counterbalanced according to location of the anomaly (i.e. in the adjective or verb), sentence length, gender, and number. Additionally, each presentation set was divided into two halves, one for the alone condition, the other for the social presence condition. Each half of the presentation set contained 50 sentences with a semantic anomaly, 50 with a syntactic anomaly, 50 correct sentences, and 50 fillers, forming a total of 200 sentences. Subjects saw each experimental sentence only once, only in one version, and only in one condition (social/alone). In total, each presentation set was presented to ten participants, yielding the total sample of 30 participants included in the analyses.

2.3. Procedure

No part of the study procedures or analyses was preregistered to the research being conducted. Participants were seated in a quiet, isolated room, approximately 70 cm in front of an LCD screen, with visual angles around $8\text{-}4^\circ$. Each trial began with a fixation cross (500 ms) in the center of the screen, followed by the rest of the sentence, presented word by word in the center of the monitor. Each word was presented for 200 ms, with an inter-stimulus-interval of 300 ms (Fig. 1). All writing was presented in white letters against a black background using

30-point Arial font. The first word of each sentence started with a capital letter, and the last word was followed by a period. One second after the sentence finished, a question mark was presented in the center of the monitor for 1.5s, during which time the participant indicated the sentence's correctness by pressing one of two buttons. The hand used for this task was counterbalanced across subjects. In order to avoid ocular artifacts during the electroencephalogram recordings, participants were asked not to blink in the time between the fixation cross and the question mark.

Both conditions of the experiment were carried out on the same day, each lasting about 30 min. In the social condition, a confederate approximately 55 cm to the participants' right, such that the confederate was within the participant's peripheral vision (see Fig. 2). The confederate was always of the same sex as the participant, and posed as a university student. The researcher explained the confederate's task in front of the participant, explaining that the confederate was participating in a trial run for an experiment on memory. The confederate, who was an actor, was audibly instructed to read the sentences being presented in order to later complete a recognition memory task, in which they would indicate which sentences had been presented. In order to seem realistic, the researcher showed them both an example of what the memory questionnaire would look like. After the participant understood their instructions, they completed a short training consisting of 24 representative sentences which were not later included in the experiment. The confederate always arrived and was explained their task after the participant had finished their training. The order of presentation of the social/alone conditions was counterbalanced across participants.

2.4. Skin conductance

Throughout the experiment, we collected information regarding participants' arousal levels by means of skin conductance recordings. An 8 channel Multibox polygraph (Brain Products, Munich) was attached to the index and middle finger of the hand not being used to respond, which was counterbalanced among participants. In order to compare

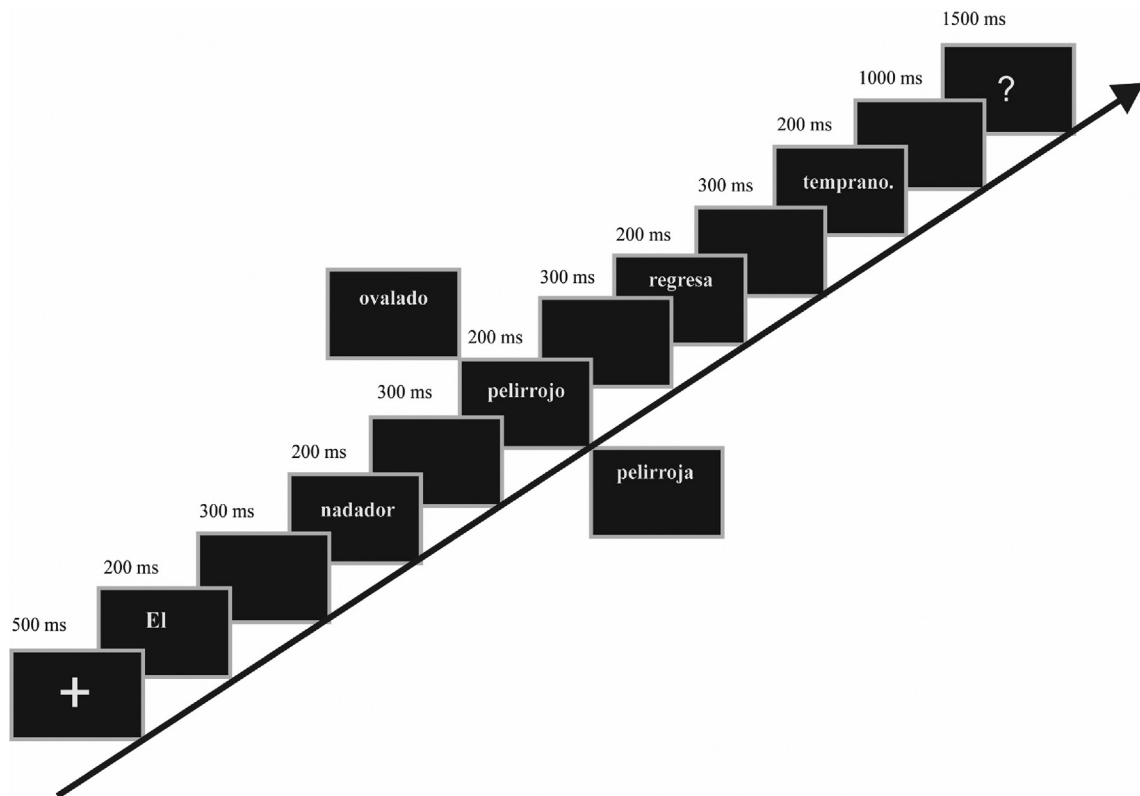


Fig. 1 – Schematic representation of the procedure: Each word in a sentence was presented for 200 ms. The sentence could be correct (center) or have a semantic (above the timeline) or a gender/number syntactic (below the timeline) disagreement in the adjective or in the verb (literal translation: *the swimmer(masc.) redhair(masc.) [correct]/oval-shaped(masc.) [semantic disagreement]/redhair(fem.) [morphosyntactic disagreement] comes back early*).

skin conductance means between conditions, subject data was first normalized. Individual measures of skin conductance recordings were averaged together for each participant separately, while the grand mean was assigned a value of 1. Therefore, skin conductance values in each social condition were compared in terms of standard deviations from the grand mean.

2.5. Electrophysiological recording and data analysis

The electroencephalogram was recorded using 60 electrodes according to the 10/20 International System. The left mastoid (M1) served as the on-line reference, recalculated off-line to M1-M2 average reference. Eye movements were recorded through electrodes placed above and below the left eye (VEOG) as well as on the outer corner of both eyes (HEOG). The continuous EEG recordings were divided into segments of 1200 ms, starting 200 ms previous to onset of the critical word (adjective or verb). All EEG data was recorded with a .01–100 Hz band-pass and offline filtered with a .1–30 Hz band-pass filter. Ocular artifacts were corrected through Independent Component Analyses (ICA). Epochs exceeding $\pm 100 \mu\text{V}$ and epochs that contained artifacts were eliminated. After removing incorrect trials and bad epochs, an average of 29.9, 30.1, and 37.5 (out of 50) correctly answered trials were

included in the data analyses for correct, semantic anomaly, and syntactic anomaly sentences, respectively.

Repeated measures ANOVAs were performed comparing clusters of electrodes constituting six regions of interest (ROI): Left Anterior (F5, F3, F1, FC5, FC3, and FC1 electrodes), Right Anterior (F2, F4, F6, FC2, FC4, FC6), Left Central (C5, C3, C1, CP5, CP3, CP1), Right Central (C2, C4, C6, CP2, CP4, CP6), Left Posterior (P5, P3, P1, PO3), and Right Posterior (P2, P4, P6, PO4). ANOVAs were performed distinctly for semantic and syntactic violations. This approach was considered the most appropriate, as opposed to overall ANOVAs containing semantic and syntactic violations simultaneously, for several reasons. First, semantic and syntactic analyses reflect different processes, based upon qualitatively different cognitive strategies. As a consequence of this, the timing at which each effect exhibits its maximum values can be different, which was particularly apparent for the LAN and N400 effects, thus determining dissimilar time windows for the most optimal statistical analyses for semantic and syntactic violations. Finally, the subsequent reduction of the levels included in the statistical comparisons would result in more robust analyses of main effects and their interactions. Each ANOVA therefore included four factors: Hemisphere (left, right), Region (anterior, central, posterior), Correctness (correct, semantically incorrect; or correct, syntactically incorrect), and Social

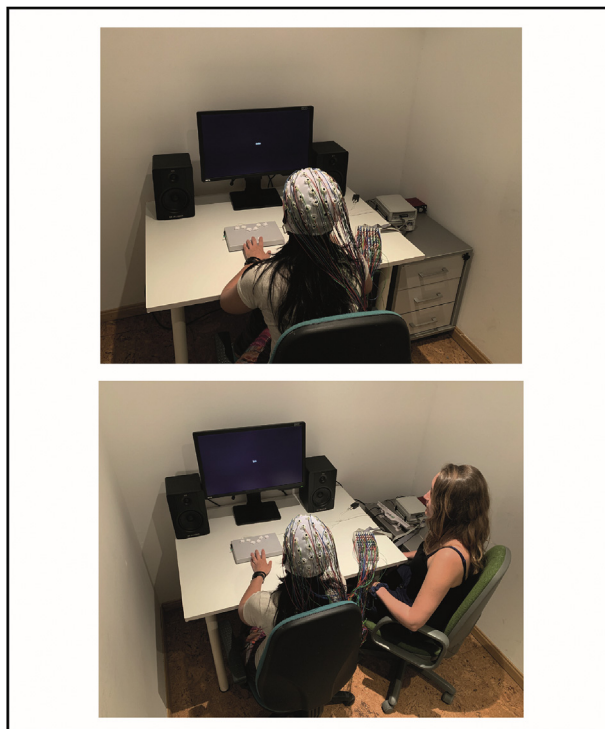


Fig. 2 – Photographs of the physical arrangement during both conditions. Top: alone condition, where the participant sat alone approximately 70 cm in front of the screen. Bottom: social presence condition, where a confederate sat approximately 55 cm to the participant's right side, in the participant's field of peripheral vision.

condition (presence, alone). Violations of the sphericity assumption were corrected when necessary by the Greenhouse-Geisser method, and *post hoc* tests were corrected by the Bonferroni method. Visual inspection of the waveforms determined the time windows used for each analysis. The 400–500 ms window was used to analyze the early syntactic (LAN) component, while the 450–550 ms window was elected to analyze the early semantic (N400) component. The 600–800 ms window was chosen to analyze the late (P600) component for both types of violations. Although the 600–700 ms and 700–800 ms windows were explored separately, using smaller windows did not significantly change the overall results. As such, the 200 ms window was preferred for simplicity.

Finally, main social presence effects were explored only in the correct sentences, to avoid odd interactions due to the qualitatively different processes involved in the linguistic anomalies, while reducing the number of factors included in the analyses and the overlap of components related to linguistic anomalies. Following visual inspection, analyses were performed in the 0–100 ms, 150–250 ms, 350–450 ms, and 650–750 ms windows (Data can be found at <https://osf.io/bh3r3>). Source analyses were also calculated for the 0–100 and 350–450 ms windows—the only windows yielding significant effects of social presence—using low-resolution

electromagnetic tomography (LORETA, Pascual-Marqui, Esslen, Kochi, & Lehmann, 2002).

3. Results

3.1. Behavioral data

The total error rate for the sentence correctness task was 27%, corresponding to 34% to correct, 31% to semantically anomalous, and 15% to syntactically incorrect sentences. An ANOVA analyses indicated that error rate did not vary significantly between social conditions ($F(1,29) = .10, p > .05, \eta_p^2 = .003, \theta = .061$), although error rate did differ significantly between sentence types ($F(2,58) = 10.72, p < .001, \eta_p^2 = .270, \theta = .963$). Specifically, syntactic anomaly sentences resulted in significantly lower error rates than correct sentences ($t(29) = 4.47, p < .001$) and sentences with a semantic anomaly ($t(29) = 4.84, p < .001$), while there was no significant difference in error rate on semantically anomalous and correct sentences ($t(29) = .48, p > .05$). These results are in line with previous studies (e.g., Martín-Loeches et al., 2012). No significant interaction between Social condition and Correctness on error rates was found ($F(2,58) = 1.06, p > .05, \eta_p^2 = .035, \theta = .201$). There was no significant effect of Social condition on reaction times ($F(1,29) = 1.01, p > .05, \eta_p^2 = .03, \theta = .162$), but there was an effect of Correctness ($F(1,29) = 10.12, p < .05, \eta_p^2 = .259, \theta = .968$), as reaction time for syntactically anomalous sentences ($M = 464$ ms) was significantly faster than for both semantically anomalous ($M = 536$ ms) and correct sentences ($M = 530$ ms) ($t(29) = 3.99, p < .001; t(29) = 4.69, p < .001$, respectively). There was no significant interaction between these two factors on reaction time ($F(1,29) = .17, p > .05, \eta_p^2 = .006, \theta = .222$).

3.2. Skin conductance data

A comparison between conditions indicated a tendency for higher arousal levels when participants were in the presence condition ($M = 1.40, SD = 1.26$) compared to when they were alone ($M = .60, SD = 1.26; t(29) = -1.761, p = .09$). Therefore, one might argue that the social condition is related to slightly higher arousal levels, but this effect was only supported by a statistical trend.

3.3. ERP data

3.3.1. Social presence effects on syntactic processing

A visual inspection of the waveforms (Fig. 3) revealed mainly left frontal negativity to morphosyntactic violations in the alone condition, which can therefore be identified as the typical left anterior negativity (LAN), in the 400–500 ms window. Along these lines, inspection of the presence condition revealed that these violations yielded a negativity with a rather central-posterior distribution. The ANOVA confirmed main Correctness effects ($F(1,29) = 14.85, p = .001, \eta_p^2 = .339, \theta = .961$), as well as a Social condition \times Region \times Correctness interaction ($F(2,58) = 4.41, p = .04, \eta_p^2 = .132, \theta = .574$).

Post hoc pairwise comparison revealed that Correctness effects were found in the anterior and central regions when

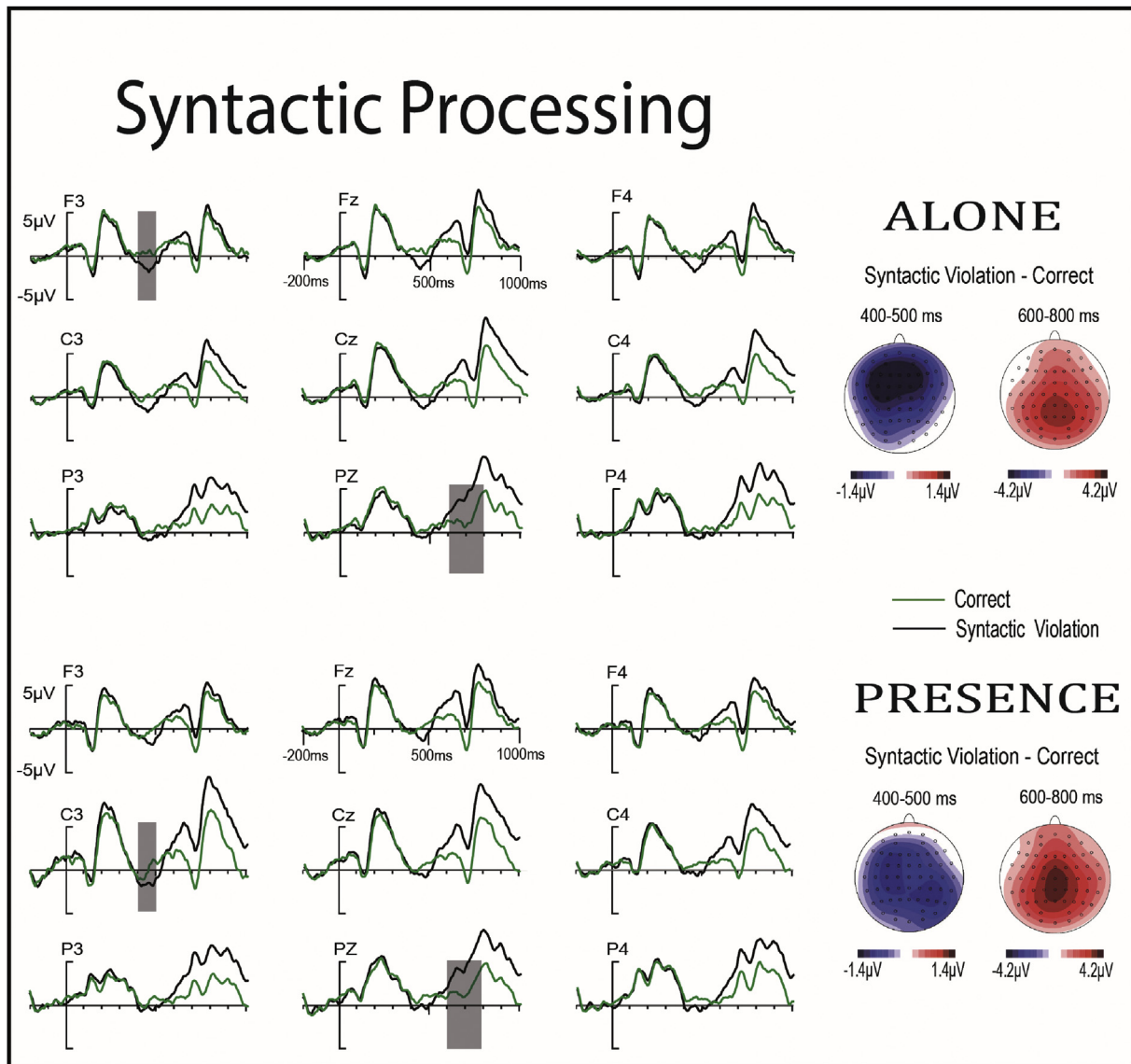


Fig. 3 – ERPs to syntactically correct and incorrect sentences alone and in social presence. Left: ERP waveforms at selected electrodes. Right: Difference maps (incorrect minus correct) of the LAN and P600 in the analyzed time windows. Color scales of the maps are symmetrical for early and late components.

alone ($\Delta = -1.151, p = .005$; $\Delta = -.777, p = .04$, respectively), while there were significant Correctness effects in the central and posterior regions in the social condition ($\Delta = -.830, p = .002$; $\Delta = -.746, p = .003$, respectively), thus substantiating the different distribution of the early negativity to morpho-syntactic violations as a function of social condition.

A later positivity was observed for morphosyntactic anomalies (Fig. 3), which can be identified as the typical P600. Visual inspections insinuated similar P600 components in social and alone conditions. The ANOVA exclusively revealed

a strong Correctness effect in the 600–800 ms window ($F(1,29) = 36.83, p < .001, \eta_p^2 = .559, \theta = 1.000$). In line with our visual inspection, the lack of Social condition interactions indicated this factor had no major impact on the P600 component elicited by syntactic violations.

3.3.2. Social presence effects on semantic processing

As can be seen in Fig. 4, a central negativity to semantic anomalies emerged in both social conditions, which can be interpreted as an N400. This was larger and showed a

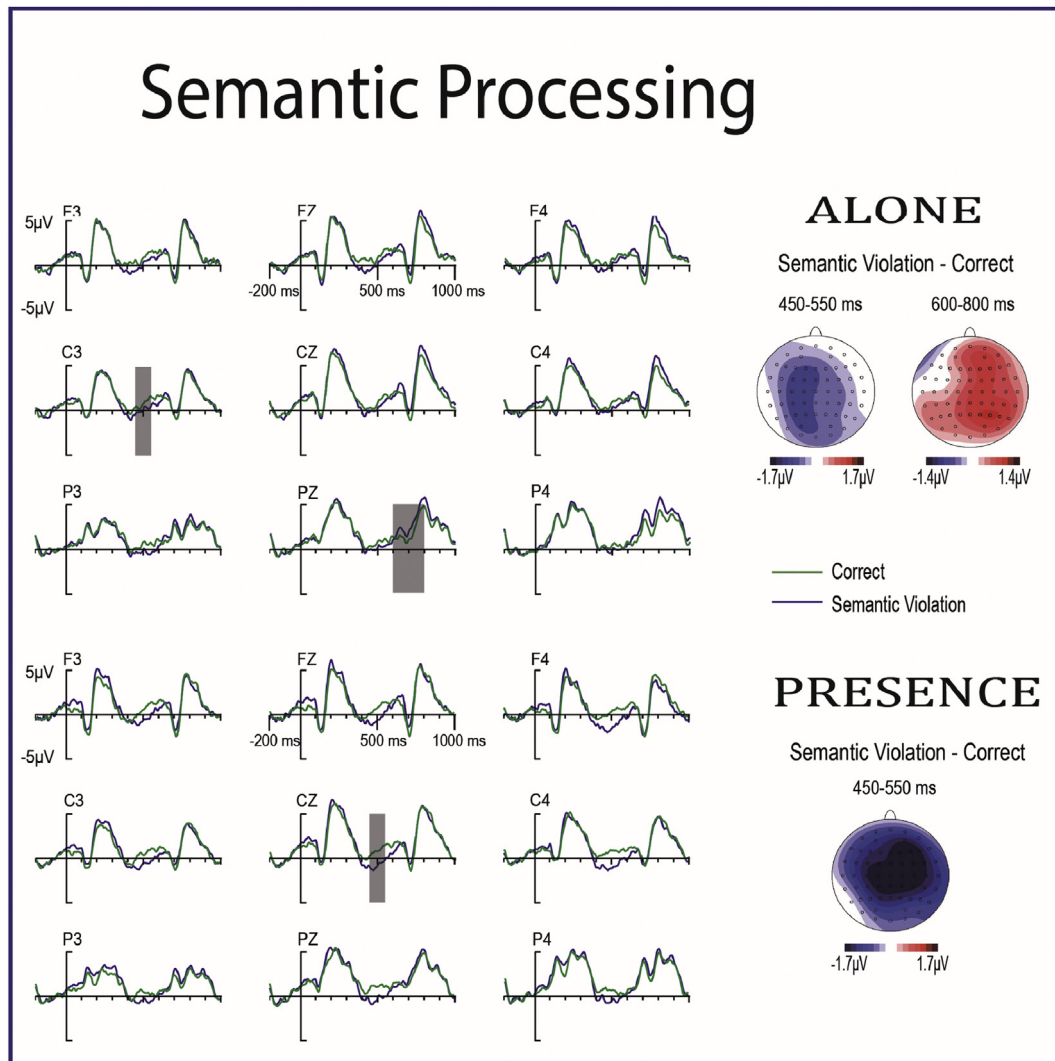


Fig. 4 – ERPs to semantically correct and incorrect sentences alone and in social presence. **Left:** ERP waveforms at selected electrodes. **Right:** Difference maps (incorrect minus correct) of the N400 P600 in the analyzed time window. Color scales of the maps are symmetrical.

relatively rightward distribution in the presence condition. The overall ANOVA was carried out in the 450–550 ms window, yielding a statistically significant correctness effect, confirming that the N400 was indeed elicited during this window in either social condition ($F(1,29) = 19.42, p < .001, \eta_p^2 = .401, \theta = .989$). The apparent differences between social conditions, however, were not supported statistically, as no significant interaction between Social condition and Correctness could be found. Notwithstanding, we decided to perform ROI post-hoc (planned) analyses to explore the possibility of finding significant differences between social conditions at this level of analyses, as Fig. 4 suggests. These revealed a significant Social condition \times Correctness

interaction ($F(1,29) = 5.008, p < .05, \eta_p^2 = .147, \theta = .581$) in the right anterior region. Taken together, our results seem to indicate that a stronger, more rightward N400 took place in the presence condition.

The P600 was hardly visible in the semantic violations. Indeed, the ANOVA in this window revealed only tendencies for a Correctness effect ($F(1,29) = 3.16, p = .09, \eta_p^2 = .098, \theta = .406$), as well as for Hemisphere \times Correctness \times Social condition ($F(2,58) = 3.84, p = .06, \eta_p^2 = .117, \theta = .475$) and Hemisphere \times Region \times Correctness \times Social condition interactions ($F(2,58) = 3.138, p = .06, \eta_p^2 = .098, \theta = .556$). However, Fig. 4 seems to indicate that whereas the alone condition exhibits a small and widely spread P600, this

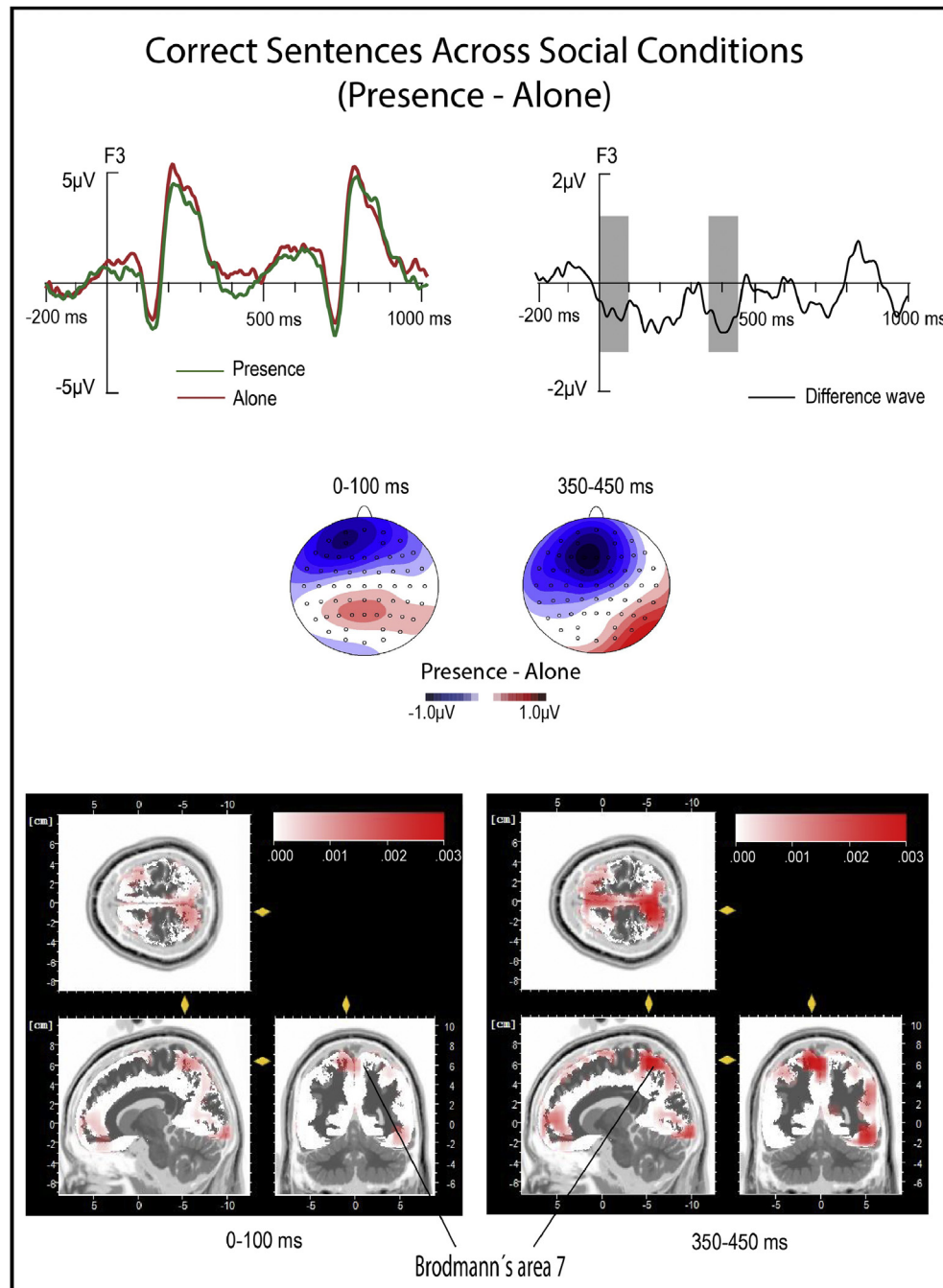


Fig. 5 – ERPs and LORETA results for correct sentences alone and in social presence. Top: ERP waveforms (left) and difference wave (right) at a selected electrode. Middle: Difference maps (presence minus alone) of the waveforms in the significant time windows. Color scales are symmetrical. Bottom: Visualization of the best candidate for ERP activation in the selected time windows.

component is absent in the presence condition. Accordingly, and as was done for the early semantic window, ROI post-hoc (planned) analyses were also performed here. These revealed a significant Correctness \times Social condition interaction ($F(1,29) = 4.65, p = .04, \eta^2 = .138, \theta = .549$) in the right anterior region, which could provide support for our observations.

3.3.3. Main social effects

In contrasting the amplitude of correct sentence trials across social conditions, a negative component in the anterior region together with a positivity at posterior regions emerged from the very beginning. This pattern apparently covered a long period of the epoch, although its plain visibility was prone to the overlap of other ERP components (see Fig. 5). The

difference wave yielded by this comparison was utilized to identify main amplitude differences between social conditions, namely in the 0–100 ms, 150–250 ms, 350–450 ms, and 650–750 ms windows, all of which yielded topographically similar results. Hemisphere \times Region \times Social condition ANOVAs were carried out in each of these windows. Analyses in the 150–250 ms and 650–750 ms windows did not reveal statistically significant effects of Social condition (all $F_s < .87$, $p > .05$), Region \times Social condition interaction (all $F_s < 1.79$, $p > .05$) nor Region \times Hemisphere \times Social condition interaction (all $F_s < 1.75$, $p > .05$).

In contrast, a significant Region \times Social condition interaction was detected in the 0–100 ms window ($F(2,58) = 5.40$, $p = .02$, $\eta_p^2 = .157$, $\theta = .694$), while the 350–450 ms window revealed significant Hemisphere \times Region \times Social condition interaction ($F(2,58) = 8.36$, $p = .005$, $\eta_p^2 = .225$, $\theta = .840$) and Region \times Social condition interaction ($F(2,58) = 3.85$, $p = .05$, $\eta_p^2 = .117$, $\theta = .512$). According to the LORETA algorithm, the best main candidate for this activation in both windows (0–100 ms, 350–450 ms) corresponds to the medial part of Brodmann's Area (BA) 7, contained within the *precuneus* (Fig. 5).

4. Discussion

In a language comprehension experiment, we examined whether the presence of another person affected participants' processing during a sentence correctness task, using semantic and morphosyntactic anomalies in the frame of an ERP investigation. Social presence did seem to affect processing: compared to when they were alone, participants in the mere presence of another person displayed a more centro-posterior early syntactic negativity (instead of the customary left anterior or LAN) and a seemingly larger early semantic component (N400). Furthermore, we detected a significant difference in amplitude for correct sentence trials when comparing across social conditions, revealing a type of social-presence-related ERP effect. This study, to the best of our knowledge, is the first to report mere presence effects on syntactic processing. As an exploratory study, we find the results bare several remarkable implications in relation to psycholinguistics and social psychology.

No effects of social presence were identified at the behavioral level (i.e., error rates or RTs). Indeed, these measures were taken late after the whole sentence had been read, that is, at a long distance from the onset of the critical words (1.7 sec for verbs, 2.2 sec for adjectives). This was sufficient time for some possible counteracting or compensatory mechanisms to emerge, dissipating any possible effects of social presence on the ultimate performance of our participants at the decision point. Finally, the observed effects have apparently been mainly restrained to the earlier stages of linguistic processing. The later P600 component, which appeared plainly to morphosyntactic mismatches, seemed unaffected by social presence in this domain. In the semantic domain, a very small P600 appeared and only in the alone condition; its nonexistence in the presence condition is probably the consequence of the augmented N400 in this condition (as discussed below). It seems, therefore, that the

close presence of another person is not meaningfully affecting the more conscious and controlled processes reflected by the P600 (e.g., [Hahne & Friederici, 1999](#)).

One remarkable finding from the present study is the change in distribution of the early syntactic (LAN) component obtained in the alone condition to a more centro-parietal distribution of the negativity in response to the same morphosyntactic violations while in the close presence of another person. The LAN has primarily been obtained in isolated conditions, which is the typical scenario reported in ERP literature thus far. What our results could indicate is that when someone is close to the participant something changes, probably as a result of a social effect. This change in topography can be interpreted as the substitution of the customary LAN to morphosyntactic violations by an N400-like component. In other words, it appears that the presence of another person has possibly triggered some change in the strategy used by the readers to process syntactic anomalies.

Comparable shifts in the strategy used to process morphosyntactic information have been reported. For instance, in [Jiménez-Ortega et al. \(2017\)](#) critical words did not elicit the LAN component to morphosyntactic violations when preceded by positively charged words, but an N400 instead. This was interpreted as a switch in the processing strategy from an algorithmic to a heuristic one, proper of transient positive emotional states ([Isen & Means, 1983](#)). Similar results have been reported when positive emotions (but not negative or neutral ones) go together with linguistic items typically eliciting a LAN (e.g., [Martín-Loeches et al., 2012](#)). N400s to morphosyntactic violations have been reported in other frames, also co-occurring with a large P600, as has been the case here. It seems that factors such as the grammatical category of the involved words can determine the prevailing type of processing strategy used to handle a morphosyntactic violation and, therefore, the appearance of one or the other component ([Molinero et al., 2015](#); [Barber & Carreiras, 2005](#)). In this regard, the more lexico-semantic information is processed the more N400-like distribution of the negativity to syntactic agreement violations (for instance, by using the cues on gender or number in the lexicon, instead of primarily matching up to the morphology of the suffixes) ([Molinero et al., 2011, 2015](#); [Bornkessel-Schlesewsky et al., 2011](#)). In our study, however, the same violated words were used in both social conditions; accordingly, the shift in the distribution of the early negativity elicited by agreement violations could be attributed only to shifts in the dominant processing strategies owing to mere presence effects.

The change in processing strategy presumably triggered by social presence can therefore be understood as the use of a more heuristic-like or associative processing style, proper of lexico-semantic operations, instead of the algorithmic and rule-based strategy, customary for morphosyntactic violations (at least in experimental setups) ([Martín-Loeches et al., 2009](#)). Although the results in this domain have not been statistically as robust as in the syntactic domain, our data suggest an N400 increase in the social presence condition for this type of sentential anomalies. Indeed, the N400 increase in this condition would be complemented by the fact that, contrasting with the alone condition, the P600 was lacking when in presence of a conspecific. Even if this finding was

again not statistically strong, it is consistent with the observation that the larger the N400 to semantic violations, the smaller—perhaps even to the point of being absent—the P600, indicating a successful integration and therefore, that reanalysis is not required (van de Meerendonk et al., 2008). Seemingly, the physical presence of another person seems to boost the heuristic mode of processing proper of the semantic domain, and for this reason the ERP component reflecting semantic processing increased in amplitude in this condition (this thereafter banishing the P600). At variance with previous reports of an N400 increase in the presence of a conspecific, our data cannot be attributed to participants' knowledge about another listener's understanding (Jouravlev et al., 2019; Rueschemeyer et al., 2014; Westley, Kohút & Resuchemeyer, 2017) because both performed independent tasks.

The potential reasons behind the observed probable effects of mere social presence on language comprehension, seemingly consisting of a boost of heuristic and associative styles of processing, remain to be discussed. Though slightly increased arousal levels were observed in the presence condition, this observation was only supported by a statistical trend; accordingly arousal does not seem to be a main contributing factor. Explanations based on social attention or cognition appear instead more applicable. Indeed, the activity observed in the social presence condition, as analyzed for the correct trials, suggests an important activation of BA7 in the precuneus when another person is close to the reader. This region is part of the so-called *default mode network* (DMN), a brain circuit largely involved in social cognition and social situational contexts (Li, Mai, & Liu, 2014). Within the DMN, the posterior regions in the precuneus/posterior cingulate seem specifically implicated in processes of evaluation about mental states of other social actors (Andrews-Hanna, 2012) and, importantly, in self-evaluative processes considering the view of other agents, as in feelings of shame or embarrassment (Takahashi et al., 2004). Finally, BA7 has also been implicated in the posterior attention system involved in responding to joint attention, which prioritizes orientation toward biologically meaningful stimuli (Mundy & Newell, 2007).

Overall, part of the attentional and processing resources of the participants seemed to be employed in pondering the close presence of a person and her/his possible mental states. Whether this directly determined a shift in the strategy to afford morphosyntactic violations, boosting associative or heuristic processing in both syntax and semantic domains, must remain as a plausible suggestion of the mechanisms involved.

In conclusion, the mere presence of a conspecific seems to impact early language processing more clearly in the syntactic than in the semantic domain. While the majority of studies on language processing have approached the issue in the frame of laboratories in social isolation conditions, the present results suggest that the picture on language comprehension would not be complete without considering the impact of having another person close to the investigated participant. Importantly, our finding relates to the effects of “mere presence” on reading, paving the way to explore the impact of social presence in other, more natural (e.g., listening) and

interactive scenarios. In this regard, it appears arguable that in the frames of conversation, competition, or joint performance, for example, the effects of social presence on language processing reported here might be magnified, even qualitatively dissimilar.

Author contributions

LJ-O and MM-L developed the study concept. CH, LJ-O, and MM-L designed the study, interpreted the data, discussed the results, and wrote the manuscript. CH and LJ-O collected and prepared the data for analysis. All authors revised the manuscript.

Open practices

The study in this article earned Open Data and Open Materials badges for transparent practices. Materials and data for the study are available at https://drive.google.com/open?id=17KmTCm9_jj0Or0vIS3EoeuAyTdzMlyNd and <https://drive.google.com/open?id=1y86wYGjrdxLaq18i6es2DHF6i9YSLE5i>.

Declaration of Competing Interest

The authors declare no commercial or financial relationships that could be interpreted as a potential conflict of interest.

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REFERENCES

- Adolphs, R. (2009). The social brain: Neural basis of social knowledge. *Annual Review of Psychology*, 60, 693–716.
- Aiello, J. R., & Douthitt, E. A. (2001). Social facilitation from Triplett to electronic performance monitoring. *Group Dynamics: Theory, Research, and Practice*, 5, 163–180.
- Allport, F. H. (1924). Response to social stimulation in the group. In F. H. Allport (Ed.), *Social psychology* (pp. 260–291). Hillsdale, NJ: Erlbaum.
- Andrews-Hanna, J. R. (2012). The brain's default network and its adaptive role in internal mentation. *The Neuroscientist: a Review Journal Bringing Neurobiology, Neurology and Psychiatry*, 18(3), 251–270.
- Ardila, A., Bernal, B., & Rosselli, M. (2017). Should Broca's area include Brodmann area 47? *Psicothema*, 29(1), 73–77. <https://doi.org/10.7334/psicothema2016.11>.
- Bara, B. G., Enrici, I., & Adenzato, M. (2016). At the core of pragmatics: The neural substrates of communicative intentions. In G. Hickok, & S. L. Small (Eds.), *Neurobiology of language* (pp. 675–688). London: Academic Press.

- Barber, H. A., & Carreiras, M. (2005). Grammatical gender and number agreement in Spanish: An ERP comparison. *Journal of Cognitive Neuroscience*, 17(1).
- Baron, R. S. (1986). Distraction-conflict theory: Progress and problems. *Advances in Experimental Social Psychology*, 19, 1–40.
- Barr, D. J., & Keysar, B. (2006). Perspective taking and the coordination of meaning in language use. In M. J. Traxler, & M. A. Gernsbacher (Eds.), *Handbook of psycholinguistics* (pp. 901–938). Amsterdam, Netherlands: Elsevier.
- Belletier, C., Normand, A., & Huguet, P. (2019). Social-Facilitation-and-Impairment effects: From motivation to cognition and the social brain. *Current Directions in Psychological Science*, 28(3), 260–265.
- Bornkessel-Schlesewsky, I., Kretschmar, F., Tune, S., Wang, L., Genc, S., Philipp, M., et al. (2011). Think globally: Cross-linguistic variation in electrophysiological activity during sentence comprehension. *Brain and Language*, 117, 133–152.
- Brown-Schmidt, S., & Heller, D. (2018). Perspective taking during conversation. In G. Gaskell, & S. A. Rueschemeyer (Eds.), *Oxford handbook of psycholinguistics*. Oxford University Press.
- Burkhardt, P. (2007). The P600 reflects cost of new information in discourse memory. *Neuroreport*, 18, 1851–1854.
- Casado, P., Martín-Loeches, M., León, I., Hernández-Gutiérrez, D., Espuny, J., Muñoz, F., et al. (2018). When syntax meets action: Brain potential evidence of overlapping between language and motor sequencing. *Cortex*, 100, 40–51.
- Casado, P., Martín-Loeches, M., Muñoz, F., Hernández-Gutiérrez, D., Jiménez-Ortega, L., Sánchez-García, J., ... Fondevila, S. (2020). On the interplay between motor sequencing and linguistic syntax: Electrophysiological evidence. *Journal of Neurolinguistics*, 53, 100874. <https://doi.org/10.1016/j.jneuroling.2019.100874>.
- Chapman, A. J. (1974). An electromyographic study of social facilitation: A test of the “mere presence” hypothesis. *British Journal of Psychology*, 65, 123–128.
- Chib, V. S., Adachi, R., & O’Doherty, J. P. (2018). Neural substrates of social facilitation effects on incentive-based performance. *Soc Cogn Neurosci*, 13(4), 391–403.
- Cottrell, N. B., Wack, D. L., Sekerak, G. J., & Rittle, R. H. (1968). Social facilitation of dominant responses by the presence of an audience and the mere presence of others. *Journal of Personality and Social Psychology*, 9(3), 245–250.
- Demolliens, M., Isbaine, F., Takerkart, S., Huguet, P., & Boussaoud, D. (2017). Social and asocial prefrontal cortex neurons: A new look on social facilitation and the social brain. *[Social Cognitive and Affective Neuroscience Electronic Resource]*, 12, 1241–1248.
- Dunbar, R. I. M. (2017). Group size, vocal grooming and the origins of language. *Psychonomic Bulletin & Review*, 24, 209–212.
- Fodor, J. A. (1983). *Modularity of mind*. Cambridge, MA: MIT Press.
- 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. (2017). *Language in our brain*. Cambridge, MA: MIT Press.
- Guerin, B. (1993). *Social facilitation*. Cambridge, UK: Cambridge University press.
- Hagoort, P. (2003). Interplay between syntax and semantics during sentence comprehension: ERP effects of combining syntactic and semantic violations. *Journal of Cognitive Neuroscience*, 15(6), 883–899.
- Hagoort, P. (2005). On Broca, brain, and binding: A new framework. *Trends in Cognitive Sciences*, 9(9), 416–423.
- Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science*, 304, 438–441.
- Hahne, A., & Friederici, A. D. (1999). Electrophysiological evidence for two steps in syntactic analysis. Early automatic and late controlled processes. *Journal of Cognitive Neuroscience*, 11, 194–205.
- Hartwick, J., & Nagao, D. H. (1990). Social facilitation effects in recognition memory. *British Journal of Social Psychology*, 29(3), 193–210.
- Hasson, U., Egidi, G., Marelli, M., & Willems, R. M. (2018). Grounding the neurobiology of language in first principles: The necessity of non-language-centric explanations for language comprehension. *Cognition*, 180, 135–157.
- Hauser, M. D., Chomsky, N., & Fitch, T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science*, 298, 1569–1579.
- He, X., Lever, A. G., & Humphreys, G. W. (2011). Interpersonal memory-based guidance of attention is reduced for ingroup members. *Experimental Brain Research*, 211, 429–438.
- Higgs, W. J., & Joseph, K. B. (1971). Effects of real and anticipated audiences on verbal learning and reproduction. *The Journal of Social Psychology*, 85, 41–49.
- Isen, A. M., & Means, B. (1983). The influence of positive effect on decision-making strategies. *Social Cognition*, 2, 18–31.
- Jiménez-Ortega, L., Espuny, J., de Tejada, P. H., 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(4), 1–13.
- Jiménez-Ortega, L., Martín-Loeches, M., Casado, P., Sel, A., Fondevila, S., de Tejada, P. H., et al. (2012). How the emotional content of discourse affects language comprehension. *Plos One*, 7(3), e33718.
- Jouravlev, O., Schwartz, R., Ayyash, D., Mineroff, Z., Gibson, E., & Fedorenko, E. (2019). Tracking colisteners’ knowledge states during language comprehension. *Psychological Science*, 30, 3–19.
- 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, 621–647.
- Larson, M. J., & Carbine, K. A. (2017). Sample size calculations in human electrophysiology (EEG and ERP) studies: A systematic review and recommendations for increased rigor. *Int J Psychophysiol*, 111, 33–41. <https://doi.org/10.1016/j.jpsycho.2016.06.015>.
- Li, Wanqing, Mai, Xiaoqin, & Liu, Chao (2014). The default mode network and social understanding of others: What do brain connectivity studies tell us. *Frontiers in Human Neuroscience*, 8, 74. <https://doi.org/10.3389/fnhum.2014.00074>.
- Martín-Loeches, M., Fernández, A., Schacht, A., Sommer, W., Casado, P., Jiménez-Ortega, L., et al. (2012). The influence of emotional words on sentence processing: Electrophysiological and behavioral evidence. *Neuropsychologia*, 50, 3262–3272.
- Martín-Loeches, M., Schacht, A., Casado, P., Hohlfield, A., Abdel Rahman, R., & Sommer, W. (2009). Rules and heuristics during sentence comprehension: Evidences from a dual-task brain potential study. *Journal of Cognitive Neuroscience*, 21, 1365–1379.
- Matchin, W., Hammerly, C., & Lau, E. (2017). The role of the IFG and pSTS in syntactic prediction: Evidence from a parametric study of hierarchical structure in fMRI. *Cortex*, 88, 106–123. <https://doi.org/10.1016/j.cortex.2016.12.010>.
- Molarino, N., Barber, H. A., Caffarra, S., & Carreiras, M. (2015). On the left anterior negativity (LAN): The case of morphosyntactic agreement: A reply to tanner et al. *Cortex*, 66, 156–159.
- Molarino, N., Barber, H. A., & Carreiras, M. (2011). Grammatical agreement processing in reading: ERP findings and future directions. *Cortex*, 47(8), 908–930.
- Monfardini, E., Redouté, J., Hadj-Bouziane, F., Hynaux, C., Fradin, J., Huguet, P., et al. (2016). Others’ sheer presence boosts brain activity in the attention (but not the motivation) network. *Cerebral Cortex*, 26, 2427–2439.

- Müller-Pinzler, L., Gazzola, V., Keysers, C., Sommer, J., Jansen, A., Frässle, S., et al. (2015). Neural pathways of embarrassment and their modulation by social anxiety. *Neuroimage*, 119, 252–261.
- Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. *Current directions in psychological science*, 16(5), 269–274.
- Niedzielski, N. (1999). The effect of social information on the perception of sociolinguistic variables. *Journal of Language and Social Psychology*, 18(1), 62–85.
- Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97–113.
- Pascual-Marqui, R. D., Esslen, M., Kochi, K., & Lehmann, D. (2002). Functional imaging with low-resolution brain electromagnetic tomography (LORETA): A review. *Methods and Findings in Experimental & Clinical Pharmacology*, 24(Suppl C), 91–95.
- Pinker, S., & Jackendoff, R. (2005). The faculty of language: what's special about it? *Cognition*, 95, 201–236.
- Platania, J., & Moran, G. P. (2001). Social facilitation as a function of mere presence of others. *The Journal of Social Psychology*, 141(2), 190–197.
- Pulvermüller, F., & Fadiga, L. (2016). Brain language mechanisms built on action and perception. In G. Hickok, & S. L. Small (Eds.), *Neurobiology of language* (pp. 311–326). London: Academic Press.
- Pylkkanen, L. (2019). The neural basis of combinatory syntax and semantics. *Science*, 366(6461), 62–66. <https://doi.org/10.1126/science.aax0050>.
- Reynaud, A. J., Guedj, C., Hadj-Bouziane, F., Meunier, M., & Monfardini, E. (2015). Social facilitation of cognition in rhesus monkeys: Audience vs. coaction. *Frontiers in Behavioral Neuroscience*, 9, 1–5.
- Rueschemeyer, S. A., Gardner, T., & Stoner, C. (2014). The social N400 effect: How the presence of other listeners affects language comprehension. *Psychonomic Bulletin & Review*, 22, 128–134.
- Schell, M., Zaccarella, E., & Friederici, A. D. (2017). Differential cortical contribution of syntax and semantics: An fMRI study on two-word phrasal processing. *Cortex*, 96, 105–120. <https://doi.org/10.1016/j.cortex.2017.09.002>.
- Schmitt, B. H., Gilovich, T., Goore, N., & Joseph, L. (1986). Mere presence and social facilitation: One more time. *Journal of Experimental Social Psychology*, 22(3), 242–248.
- Shultz, S., Lee, S. M., Pelphrey, K., & McCarthy, G. (2011). The posterior superior temporal sulcus is sensitive to the outcome of human and non-human goal-directed actions. *Social cognitive and affective neuroscience*, 6(5), 602–611.
- Somerville, L. H. (2013). The teenage brain sensitivity to social evaluation. *Curr Dir Psychol Sci*, 22, 121–127.
- Statum Casasanto, L. (2008). Does social information influence sentence processing? In B. C. Love, K. McRae, & V. M. Sloutsky (Eds.), *Proceedings of the 30th annual conference of the cognitive science society* (pp. 799–804). Austin, TX: Cognitive Science Society.
- Steinhauer, K., & Connolly, J. F. (2008). Event-related potentials in the study of language. In B. Stemmer, & H. A. Whitaker (Eds.), *Handbook of the neuroscience of language* (pp. 91–104). New York: Elsevier.
- Takahashi, H., Yahata, N., Koeda, M., Matsuda, T., Asai, K., & Okubo, Y. (2004). Brain activation associated with evaluative processes of guilt and embarrassment: An fMRI study. *Neuroimage*, 23, 967–974.
- Tomasello, M., Call, J., & Hare, B. (2003). Chimpanzees versus humans: it's not that simple. *Trends in Cognitive Sciences*, 7, 239–240.
- van de Meerendonk, N., Kolk, H. H. J., Vissers, C., & Chwilla, D. J. (2008). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. *Journal of Cognitive Neuroscience*, 22, 67–82.
- Westley, A., Kohút, Z., & Rueschemeyer, S. A. (2017). “I know something you don't know”: Discourse and social context effects on the N400 in adolescents. *Journal of Experimental Child Psychology*, 164, 45–54.
- Yoshie, M., Nagai, Y., Critchley, H. D., & Harrison, N. A. (2016). Why I tense up when you watch me: Inferior parietal cortex mediates an audience's influence on motor performance. *Scientific Reports*, 6(1), 19305.
- Zaccarella, E., Meyer, L., Makuuchi, M., & Friederici, A. D. (2015). Binding by syntax: The neural basis of minimal linguistic structures. *Cerebral Cortex*, 27(1).
- Zajonc, B. (1965). Social facilitation. *Science*, 149(July), 269–274.
- Zajonc, R. B. (1980). Presence. In P. B. Paulus (Ed.), *Psychology of group influence*. Hillsdale, NJ.