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Objects, events and "to be" verbs in Spanish – An ERP study of the syntax–semantics interface

Barbara Leone-Fernandez [a,*], Nicola Molinaro [b], Manuel Carreiras [b,c,d], Horacio A. Barber [a]

[a] Departamento de Psicología Cognitiva, Universidad de La Laguna, Tenerife, Spain
[b] Basque Research Center on Cognition Brain and Language, Donostia-San Sebastián, Spain
[c] IKERBASQUE, Basque Foundation for Science, Bilbao, Spain
[d] Departamento de Filología Vasca, University of the Basque Country (UPV/EHU), Bilbao, Spain

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ABSTRACT

In Spanish, objects and events at subject position constrain the selection of different forms of the auxiliary verb "to be": locative predicates about objects require "*estar en*", while those relating to events require "*ser en*", both translatable as "to be in". Subjective ratings showed that while the "*object + ser + en*" is considered as incorrect, the "*event + estar + en*" combination is also perceived as unacceptable but to a lesser degree. In an ERP study, we evaluated the impact of a purely semantic distinction (object versus events) on the subsequent processing of these auxiliary verbs followed by locatives in Spanish. For the "*ser en*" predicate, the P600 component was larger when the subject was an object than when it was an event. This P600 effect is consistent with an online repair of the defining predicate when it does not fit with the adequate semantic properties of the subject. On the other hand, for the "*estar en*" predicate, event subjects when compared to object subjects showed more positive ongoing amplitudes between 280 and 380 ms after the presentation of the "*en*" preposition, followed by a longer positive wave starting around 400 ms and lasting until 700 ms after the presentation of the following determiner, with central and frontal scalp distributions respectively. Thus, the different subject-predicate combinations, depending on the semantic features of the subjects, triggered syntactic reparatory processes at a structural level. These findings are consistent with an incremental interpretation of sentence meaning based on the interaction between syntactic and semantic information.

1. Introduction

In the present study we look at the interaction between syntactic and semantic information during language comprehension. Sommers (1965) proposed that there is an explicit relation between the natural use of language represented by syntactic constraints and knowledge of the world at the semantic level. Thus, combinations of nouns and verbs reflect interactive processing such that semantic information could play a crucial role in selecting one particular syntactic structure over another. One representative candidate for this interaction seems to be the use of locative predicates in Spanish: *ser en* and *estar en* (both translatable in English as "to be in"). In this type of structure, the selection of either of these specific syntactic locative predicates varies depending on the semantic properties of the noun in subject position, whether an event or a concrete object, as can be seen from the following sentences:

1. *La fiesta es en la cocina.* The party [+Ev] is [+Ser] in the kitchen.
2. *La silla está en la cocina.* The chair [+Obj] is [+Estar] in the kitchen.

In the following, we will introduce the qualitative difference between the use of the *ser en* and *estar en* locative predicates in Spanish. Then, we will describe in more detail previous studies that have investigated how syntactic choice of these locative predicates (*ser* vs. *estar*) is associated to a semantic category distinction (object or event) in subject position. Finally, we will discuss how studying the online comprehension of locative predicates in Spanish in terms of their neurophysiological correlates helps to better understand the relation between the semantic category of the noun and the processing of syntactic rules.

1.1. Ser en versus estar en predicates

According to the traditional distinction, in Spanish, the verb *ser* describes inherent realities and *estar* describes temporary/changeable realities. Thus, the spatial location of an object is a temporary/changeable feature, so the verb *estar* is required. In contrast, the

* Corresponding author. Address: Departamento de Psicología Cognitiva, Universidad de La Laguna, 38205 Tenerife, Spain. Fax: +34 922317461.
E-mail address: bleone@ull.es (B. Leone-Fernandez).
URL: http://www.neurocog.ull.es/ (B. Leone-Fernandez).

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spatial location of an event can be considered as an inherent characteristic and therefore the verb *ser* is used. However, one argument against this account is that the property of permanency is not indicative of enough realities to define any linguistic parameter, be it syntactic or semantic. In fact, very few elements in reality, concrete or otherwise, are empirically unchangeable, or truly permanent. Kratzer (1995) explained this semantic phenomenon using a syntactic criterion that distinguishes between an individual level for the use of the verb *ser* and a stage level for the use of *estar*. The *ser* predicate, which seems not to be temporally bound, would fall under the individual-level designation, because it is used most of time to describe essential properties. The *estar* predicate, which applies at one given point in time or within one set time frame, would fall under the stage-level designation, because it is mainly used for describing properties that are temporary and transitory. Additionally, stage-level predicates contain an extra argument position for events or spatiotemporal locations and individual-level predicates do not. Stage-level predicates would be analyzed as eventive in nature, taking place at a particular period of time and place, unlike individual-level predicates. Therefore according to the syntactic dichotomy between stage and individual-levels (Kratzer, 1995), when describing spatial properties, both objects and events could be combined with the *estar* predicate, but only events could be combined with the *ser* predicate. Another approach to this question is that of Maienborn (2005), who proposed a pragmatic discourse-based account of "to be" Spanish verbs where, although semantically identical, these copulas differ in that *estar* presupposes a discourse anchorage while *ser* does not: this difference allows the speaker to mark different perspectives on a predicate in a particular discourse. Thus, the form *ser* can refer to general situations, while the form *estar* refers always to a particular situation. According to this account, the use of *ser* or *estar* would depend especially on semantic and pragmatic interpretations. What these positions on the *ser*/*estar* distinction have in common is the idea that these verbs vehicle different meaning. However, while Kratzer's account considers the semantic differences between these two copulas to be syntactically constrained, a semantic/pragmatic explanation has been inferred by Maienbourn's account. Thus, it remains unclear how, when and under what circumstances the semantic category of the subject noun plays a role in the on-line interpretation of these predicates.

1.2. Behavioral studies

Sera, Gathje, and Pintado (1999) investigating processing of the "*ser*/*estar* + *en*" combination in locative predicates, showed how verb selection depends on contextual factors. They asked Spanish speakers to indicate which sentences were anomalous in utterances defining the spatial properties of both objects and events. A sentence was to be considered anomalous when the only way in which it made sense was to interpret it metaphorically (see experimental instructions pages 308–309). We should note that this was not a strictly syntactic judgment task, but a more general evaluation of the naturalness of the sentences. They presented, among others, sentences in which the locative construct could use either the verb *ser* or the verb *estar* for both objects and events and reported the percentage of participants who considered the sentences natural. Their results are reported in Table 1.

For *ser*, the difference between objects and events was clear-cut: the sentences with an event in subject position were evaluated as more natural utterances than those with an object in subject position. In the case of *estar*, the data were more balanced between both types of nouns. These data are consistent with Kratzer's (1995) proposal. The spatial location of an object has to be combined with the *estar* predicate (stage-level), while the spatial location of an event is usually combined with the *ser* predicate (individual-level), but can also be acceptable in association with the *estar* predicate (stage-level).

Table 1
Mean percentage of times Spanish speakers rated as natural spatial predicates with objects and events in Sera et al. (1999; Experiment 1).

	Object	Event
Spatial predicate		
Ser	1.3*	92.5
Estar	78.9	67.8

* Statistical differences (see text); $p<.05$.

However, since Sera et al. (1999) asked for anomaly evaluation and did not require their participants to perform a syntactic judgment task, the phenomenon is still undefined on a semantic/syntactic dimension. For this reason, we ran a pre-test on the grammaticality of these stimuli where we asked Spanish students to make a grammaticality judgment (see the Pre-test in the Section 2). The data for *ser* mirror the difference reported by Sera et al. (1999) in that the sentences headed by a concrete object were considered incorrect, while the sentences headed by an event were evaluated as correct. Contrary to the naturalness judgments reported by Sera and colleagues, however, the data for *estar* were clear-cut: the sentences with a concrete object in subject position were considered correct while the event sentences were evaluated as incorrect (the results are reported in Table 2). These results indicate that when Spanish speakers are required to make an overt syntactic judgment about the type of locative predicate that is required by objects and events, they make a categorical distinction: concrete objects require *estar en* while events require *ser en*. However, as shown by the naturalness ratings reported by Sera et al. (1999), in their everyday use of language, Spanish speakers are less strict in the selection of the locative predicate for events, as evidenced by the similar pragmatic acceptability of *ser en* and *estar en*. It is clear, however, that concrete objects in subject position need the *estar en* predicate. In sum, the behavioral data, although partially contradictory, indicate that there could be different uses of these locative predicates as combined with objects and events.

1.3. ERPs and sentence reading

The present study is aimed at investigating the on-line processing of locative predicates in Spanish by means of Event-Related Potentials (ERPs), which allow tracking of changes in the electrical activity of the brain associated to the processing of each word in the sentence. Cognitive neuroscientists have detailed many aspects of ERP differences which correlate with the processing of semantic and syntactic processing.

The N400 (Kutas & Hillyard, 1980) is an enhanced centro-parietal negative-going wave peaking at about 400 ms after a semantic violation in a sentence. Specifically, it has been shown that the N400 amplitude is a linear function of word predictability (operationalized by off-line cloze probability); the more predictable a word, the smaller the N400 (Kutas & Federmeier, 2000; Kutas, Van Petten, & Kluender, 2006; Molinaro, Conrad, Barber, & Carreiras, 2010).

Table 2
Means and standard deviations of times Spanish speakers rated as grammatically correct spatial predicates with objects and events.

	Object	Event
Spatial predicate		
Ser	6.8 (SD 4.0)*	34.6 (SD 4.8)
Estar	37 (SD 3.8)	10.8 (SD 4.7)*

* Statistical differences (see text); $p<.05$.

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A later ERP response between 500 and 850 ms, known as the P600, has been associated with syntactic violations (Barber & Carreiras, 2005; Hagoort, Brown, & Groothusen, 1993; Osterhout & Mobley, 1995; Vos, Gunter, Kolk, & Mulder, 2001). It has been argued that this late positivity could be a member of the P300 family- namely the so called P3b component (Coulson, King, & Kutas, 1998), which is elicited by unexpected or infrequent events. Independently of whether the P600 is linguistically specific or not, there is some agreement that the P600 is the result of different subcomponents associated to different cognitive operations (Friederici, Mecklinger, Spencer, Steinhauer & Donchin, 2001; Molinaro, Barber, & Carreiras, submitted for publication). In particular, the P600 has been related to processes of revision and/or repair in sentence processing (Meltzer, McArdle, Schafer, & Braun, 2009; Molinaro, Kim, Vespignani, & Job, 2008). It is reportedly elicited by words that are either ungrammatical continuations of the preceding sentence fragment and trigger repair processes (e.g. Hagoort et al., 1993) or non-preferred continuations of the preceding sentence fragment, which trigger revision processes (Carreiras, Salillas, & Barber, 2004; Osterhout & Holcomb, 1992). However, more recent work has shown evidence that this simple differentiation between syntax and semantic processes could be unsustainable (see Bornkessel-Schlesewsky & Schlesewsky, 2008; Kuperberg, 2007 for reviews). More specifically, it has become clear that other ERP components can reflect semantic processing in the absence of N400-type effects and not only syntactic information affects the P600. For instance, Hagoort (2003) found the N400 to single semantic violations was increased in amplitude by an additional syntactic violation, whereas the P600 to single syntactic violations was unaffected by an additional semantic violation. Bornkessel, McElree, Schlesewsky, and Friederici (2004) reported an N400 – classically associated with semantic processing difficulties – at the verb for syntactic manipulations, e.g. case-ambiguous object-initial sentences that are disambiguated at dative verbs. Further, Kim and Osterhout (2005) observed a P600 rather than an N400 at the position of the verb in sentences such as "*The hearty meal was devouring…*" In summary, the outcome of all this evidence about N400 and P600 responses is that in contrast to the standard assumption, ERP effects classically assumed to be purely syntactic in nature (i.e. P600) can be affected by semantic information, and effects related to meaning construction (i.e. N400) can be affected by syntactic parsing.

1a	*La fiesta es en la cocina*	The party [+Ev] is [+Ser] in the kitchen
1b	∗*La silla es en la cocina*	The chair [+Obj] is [+Ser] in the kitchen
2a	*La silla está en la cocina*	The chair [+Obj] is [+Estar] in the kitchen
2b	??*La fiesta está en la cocina*	The party [+Ev] is [+Estar] in the kitchen

1.4. The present study

In the present study, the processing of the two forms of the Spanish auxiliary verb "to be" (*ser* and *estar*) is examined in relation to their preferred subject nouns: concrete objects or events. To this end we used sentences such as those in (1) and (2):

In sentences like (1a) the subject is an event and is followed by its congruent *ser en* predicate, while in (1b) a concrete object is associated with the same construct, which is considered syntactically ill-formed and anomalous. Alternatively, the *estar en* predicate is required by a concrete object (2a), while for an event (2b) it is considered syntactically ill-formed but more acceptable (as supported by questionnaires reported in the Section 2).

Understanding how the semantic categories of objects and events work with the Spanish "to be" copulas within locative predicates could provide supporting evidence to distinguish between the two different theoretical views of the *ser*/*estar* distinction previously discussed (the individual/stage level distinction of Kratzer (1995) and Maienborn's (2005) discourse-based interpretation. To this end, we compared ERPs time-locked to the presentation of the preposition *en*, comparing sentences such as (1a) with those such as (1b), and (2a) with (2b). Both (1b) and (2b) sentences can have an acceptable continuation (for example, an adjective) at the verb position; in other words, the locative predicate is explicit only at the presentation of the preposition, which is the point at which they become syntactically unacceptable. Given the objects/events semantic distinction, we could expect both unacceptable constructs – the *ser en* (1b) and the *estar en* (2b) – to elicit ERP effects in terms of their semantic and pragmatic factors, namely a N400 component, but not in syntactic terms, as compared to their respective controls. As suggested by Maienborn (2005), semantic and pragmatic factors could be fundamental to the interpretation of object + *ser en* and event + *estar en* constructs, as described in their discourse-based account. Although, as our pre-test questionnaire has shown (see Section 2), Spanish speakers judged both combinations (1b) and (2b) as syntactically unacceptable. Therefore, we considered that both (1b) and (2b) sentences could elicit the same ERP effect, namely a P600 component. This would indicate that Spanish speakers are sensitive mainly to the syntactic restrictions of noun and verb combinations. As suggested by Kratzer (1995), semantic distinction between objects and events will be triggered at the level of the syntactic stream during sentence processing. However, the event + *estar en* construct has been considered semantically understandable by anomaly judgment tests (Sera et al., 1999). Thus, the differences between the object + *ser en* and the event + *estar en* constructs could modulate the P600 effect or some other subcomponents of the P300 family. Following these predictions, if both object + *ser en* and event + *estar en* combinations affect the syntactic processing, only Kratzer's view (1995) will be supported: syntactic violations can depend on the semantic representation of categories (concrete objects versus events).

2. Method

2.1. Stimuli

We used a set of 160 experimental sentences. Half of them had an object as subject and half of them had an event. All objects and events used were matched for Lexical Frequency (mean Log_10 = 1.12 and SD = 0.52 for the objects vs. mean Log_10 = 1.23 and SD = 0.44 for the events), Number of Neighbors (mean number of Neighbors = 1.33 and SD = 3.46 for the objects vs. mean number of Neighbors = 1.65 and SD = 3.67 for the events) and Familiarity (mean Familiarity = 4.59 and SD = 2.59 for the objects vs. mean familiarity = 4.44 and SD = 2.39 for the events) using lexical entries of the B-pal software (Davis & Perea, 2005). We also ran a *T*-test for the Log_10 of Lexical Frequency and for Familiarity which both turned out to be not significant (t (79) = −1.42, p = 0.15); (t (79) = −0.379, p = 0.706). The t-test for Number of Neighbors revealed no effect (t (79) = −0.54, p = 0.58).

We then constructed two versions of each sentence, one with the verb *ser* and one with the verb *estar*. The experimental design entailed a two by two structure: two possible nouns in subject position (*object* or *event*) followed by two possible versions of the verb "to be" in Spanish. All the sentences had the same structure: a subject (either an object or an event) followed by the verb,

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followed by a prepositional phrase introduced by the preposition *en* (“in”), as show in (1). Sentences were divided into two lists, so that the same object or event was followed by a different predicate (either *ser en* or *estar en*) in the two lists.

2.2. Pre-tests and participants

Before the experiment, 30 Spanish speakers filled out a questionnaire to evaluate syntactic acceptability judgments. The group of volunteers who participated in the pre-test and saw all the experimental sentences was not the same as the group in the EEG study. Sentences were evaluated on a seven-point scale: from 1 (completely correct), through 3 (unusual sentence) and 4 (barely acceptable), to 7 (completely incorrect). Across the conditions, the mean values showed: for the object, participants clearly preferred *estar en* as opposed to *ser* (object + *estar en*: mean = 1.54, SD = 0.52; object + *ser en*: mean = 5.57, SD = 1.01). For the event, the data was less rigid: event + *ser en* was considered completely correct while event + *estar en* was judged between barely acceptable and completely incorrect (event + *ser en*: mean = 1.92; SD = 0.65; event + *estar en*: mean = 4.35; SD = 1.17).

A 2×2 ANOVA was carried out with the following factors: Predicate (*ser en* vs. *estar en*) and Correctness (correct structure vs. incorrect structure). The results revealed a main effect of Predicate $F(1, 29) = 304.008$, $p = .00$ and a main effect of Correctness $F(1, 29) = 848.850$, $p = .00$. As predicted, we did not find an interaction between Predicate and Correctness: for *ser en*, Spanish students evaluated sentences headed by an event as correct, while sentences headed by an object were incorrect; on the contrary, for *estar en*, sentences headed by an object were considered correct more than sentences headed by an event.

For the ERP experiment we tested 30 native Spanish speakers (17 female and 13 male), with no history of neurological or psychiatric impairment and with normal or corrected to normal vision. All of them were volunteers. All participants (mean age: 21.1 years, age range: from 18 to 35 years) were right-handed, as assessed by a Spanish version of the Edinburgh Handedness Inventory (Oldfield, 1971).

2.3. Procedure

After giving informed consent and having the electrode cap applied, participants were seated comfortably in a darkened sound-attenuated room. Stimuli were displayed on a computer monitor in white letters against a black background. Participants were seated about 70 cm from the monitor. The sentences were presented visually, one word at a time in the center of a computer screen: first, a fixation point (“+”) appeared in the center of the screen for 2700 ms during which time participants were allowed to blink. This fixation point was followed by a blank screen interval of 300 ms, after which the first word of a sentence appeared. The words were presented for 300 ms; SOA between words within each sentence was 600 ms, followed by a 300 ms blank interval. The inter-trial interval varied randomly between 700 and 1300 ms.

In addition to the experimental sentences, a set of 160 filler sentences of similar length and sentence structure but with variable violations (half of the fillers were correct and the other half incorrect) were included in order to obtain more heterogeneous material. Each participant read 320 sentences in total. At the end of each sentence participants had to judge if the sentence was correct or incorrect by pressing a Yes/No button. Participants were encouraged to respond quickly and correctly to the task. For half of the participants the right button was the “Yes” response and the left button was the “No” response. For the other subjects, the order was reversed. Participants were also asked to avoid eye movements and blinking during the interval when a fixation asterisk was not present. All trials were presented in a different pseudorandom order for each participant.

2.4. EEG recording and analysis

Scalp voltages were collected from Ag/AgCl electrodes through 32-channels Easy-cap with the BrainAmp system. The left mastoid was used as reference during recording. Eye movements and blinks were monitored via electrodes placed on the superior and inferior orbital ridges and the outer canthi. Impedances were kept below 10 kΩ for all the electrodes and the EEG was recorded with an analogue band-pass filter of 0.01–100 Hz (plus a 50 Hz notch filter). The signal was digitally sampled throughout the whole session with a sampling rate of 256 Hz. The continuous EEG was re-referenced off-line to the average activity between the two mastoids and filtered with a digital 35 Hz low-pass filter.

The ERPs time-locked to the target preposition *en* were selected based on marker positions from 200 ms before to 1500 ms after the target event. Epochs with an excessive number of artifacts were excluded from the following analysis. This resulted in a rejection of 14.8% of epochs on average across conditions. Baseline correction was performed using the average EEG activity in the 200 ms preceding the onset of the target word (the preposition *en*). Separate ERPs were obtained averaging the single epochs of interest for each of the experimental conditions, each of the subjects and each of the electrode sites. The following statistical analyses were conducted on the average activity within specific windows of interest selected from the visual inspection of the grand-averaged waveforms.

Separate analyses of variance were conducted on the midline electrodes (Fz, Cz, Pz) and on six regions of interest, each containing the average values of a group of four electrodes. The six regions were grouped in this way between the two hemispheres (left and right): left anterior (LA: average between F7, F3, FC5, Fp1), left central (LC: FC1, C3, CP5, T7), left posterior (LP: CP1, P7, P3, O1), right anterior (RA: F4, F8, FC6, Fp2), right central (RC: FC2, C4, CP6, T8), right posterior (RP: CP2, P4, P8, O2). Mean amplitudes were obtained for different time windows.

At the preposition, we separately compared the processing of *ser en* and *estar en* predicates. The analyses in the Midline electrodes were planned using a two-way ANOVA with Electrode (three levels: Fz, Cz and Pz) and Syntactic acceptability (Syntactically acceptable vs. Syntactically unacceptable) as factors. In the lateralized groups we ran a three-way ANOVA (indicated as Region analysis) with Hemisphere (left vs. right), Region (three levels: Frontal, Central and Parietal) and Syntactic acceptability (Syntactically acceptable vs. Syntactically unacceptable) as factors. Where appropriate, critical values were adjusted using the Greenhouse–Geisser correction. Effects for the topographical factors will only be reported when they interact with the experimental manipulations. For all significant effects, we report 95% confidence intervals (CI) for the differences between condition means computed using the mean square error terms from the analysis by participants (Loftus & Masson, 1994; Masson & Loftus, 2003). Post-hoc comparisons were carried out through paired sample *t*-tests run in a pairwise manner for each region between the two critical conditions. *T*-values were corrected using the False Discovery Rate correction (Benjamini & Hochberg, 1995).

3. Results

3.1. Behavioral measures

Responses to the correctness judgment task performed after the reading of each sentence were analyzed, calculating the mean

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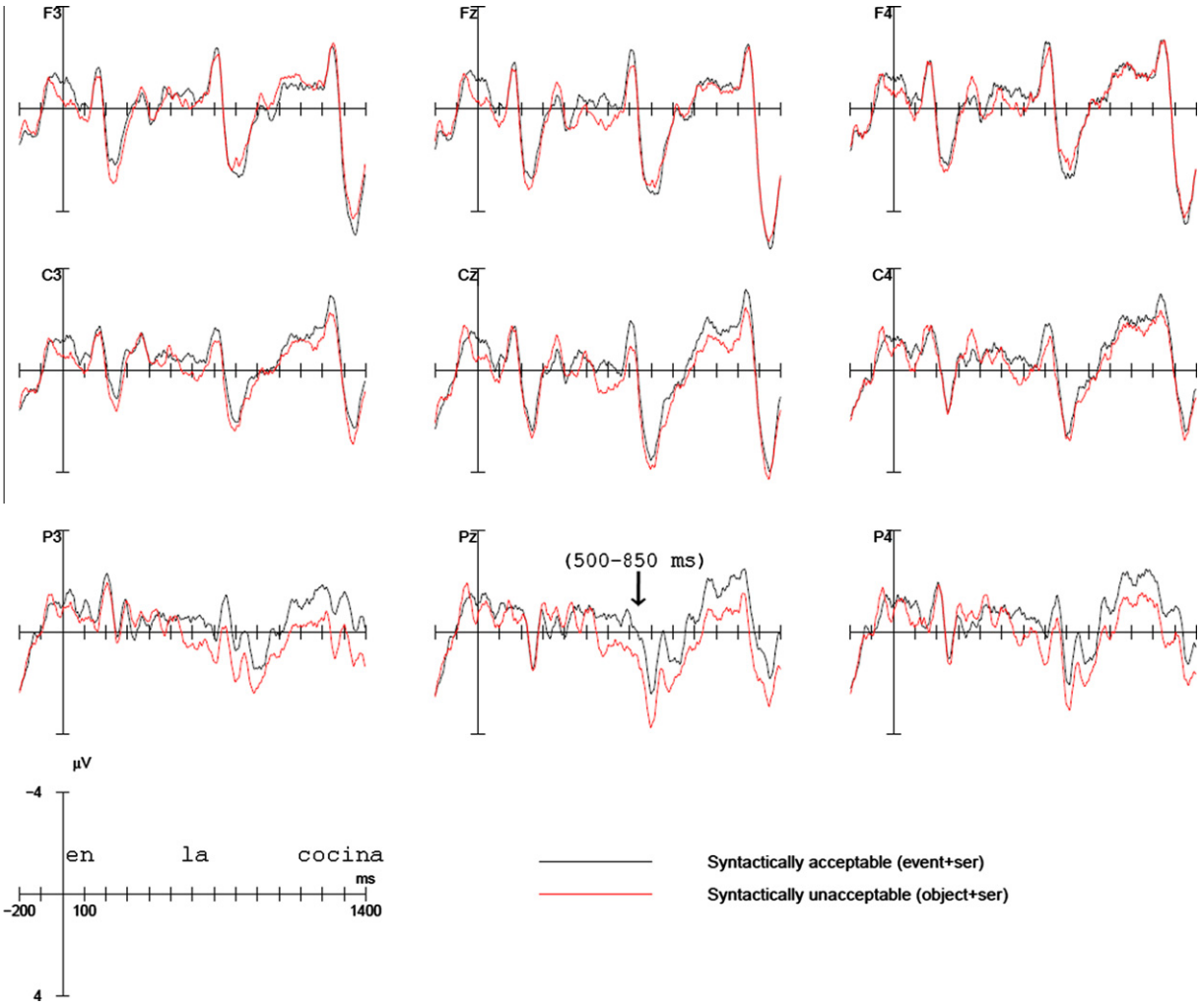

Fig. 1. Grand-averaged ERPs of the *ser en* predicate, time-locked to the *en* preposition. The black line refers to the syntactically acceptable combination (*ser en* headed by an event) and the red line refers to the syntactically unacceptable combination (*ser en* headed by an object). Negative values are plotted up.

percentages of incorrect answers for the different conditions: event + *ser en* (syntactic acceptable) = 15.75%; object + *ser en* = 13.08% (syntactic unacceptable); object + *estar en* (syntactic acceptable) = 9.83%; and event + *estar en* (syntactic unacceptable) = 40.25%. An ANOVA on these percentages was conducted including the factors "Verb" (*ser* versus *estar*), and "Correctness" (correct versus incorrect). This ANOVA showed a significant interaction between Verb and Correctness, $F(6, 154) = 46.187$, $p < .00$). Post-hoc comparison showed significant differences between the event + *estar en* versus object + *estar en* conditions $t(29) = .8.430$, $p < .00$; between the event + *estar en* versus object + *ser en* conditions $t(29) = 8.611$, $p < .00$; and between the event + *estar en* and event + *ser en* conditions $t(29) = -6.804$, $p < .00$. *T*-values were corrected using the False Discovery Rate correction (Benjamini & Hochberg, 1995). These results show that participants produced significantly more errors with the unacceptable combination of the predicate *estar en* than in the rest of the conditions.

3.2. Electrophysiological measures

Figs. 1 and 2 plot grand average waveforms corresponding to the different experimental conditions. The event + *ser en* versus the object + *ser en* combinations are compared in Fig. 1, whereas the object + *estar en* versus the event + *estar en* combinations are compared in Fig. 2. For both comparisons, the ERP data are time locked to the presentation of the preposition *en* (in), and the analyzed segment (1230 ms) overlapped with the presentation of the determiner *la* (the) determiner. Lexical differences,[1] such as word length and frequency, between the verbs *ser* and *estar* prevent their direct comparison.

Visual inspection of Fig. 1 reveals differences between the event + *ser en* condition and the object + *ser en* condition, starting around 500 ms after the preposition presentation, and lasting until the end of the analyzed segment. The object + *ser en* condition was more positive than the event + *ser en* condition, with the largest amplitude differences at 600 ms. Fig. 2 also reveals differences between the object + *estar en* and the event + *estar en* conditions in the 280–380 ms time window relative to the preposition onset presentation. The event + *estar en* condition showed more positive amplitudes than the object + *estar en* condition. Later, after the presentation of the determiner, another difference between conditions can be observed. Between 930 and 1230 ms (400–700 ms time window with respect to the determiner onset presentation), the event + *estar en* condition showed more positive amplitudes than the object + *estar en* condition. The subtraction of the respective

[1] For example, there is a significant difference in the frequency of the two verbs, as well as in the frequency of the combinations *estar en* and *ser en*. The number of entries in the Google internet-search tool was 427.000.000 for *ser*, 151.000.000 for *estar*, 224.000.000 for *ser en* and 86.200.000 for *estar en*.

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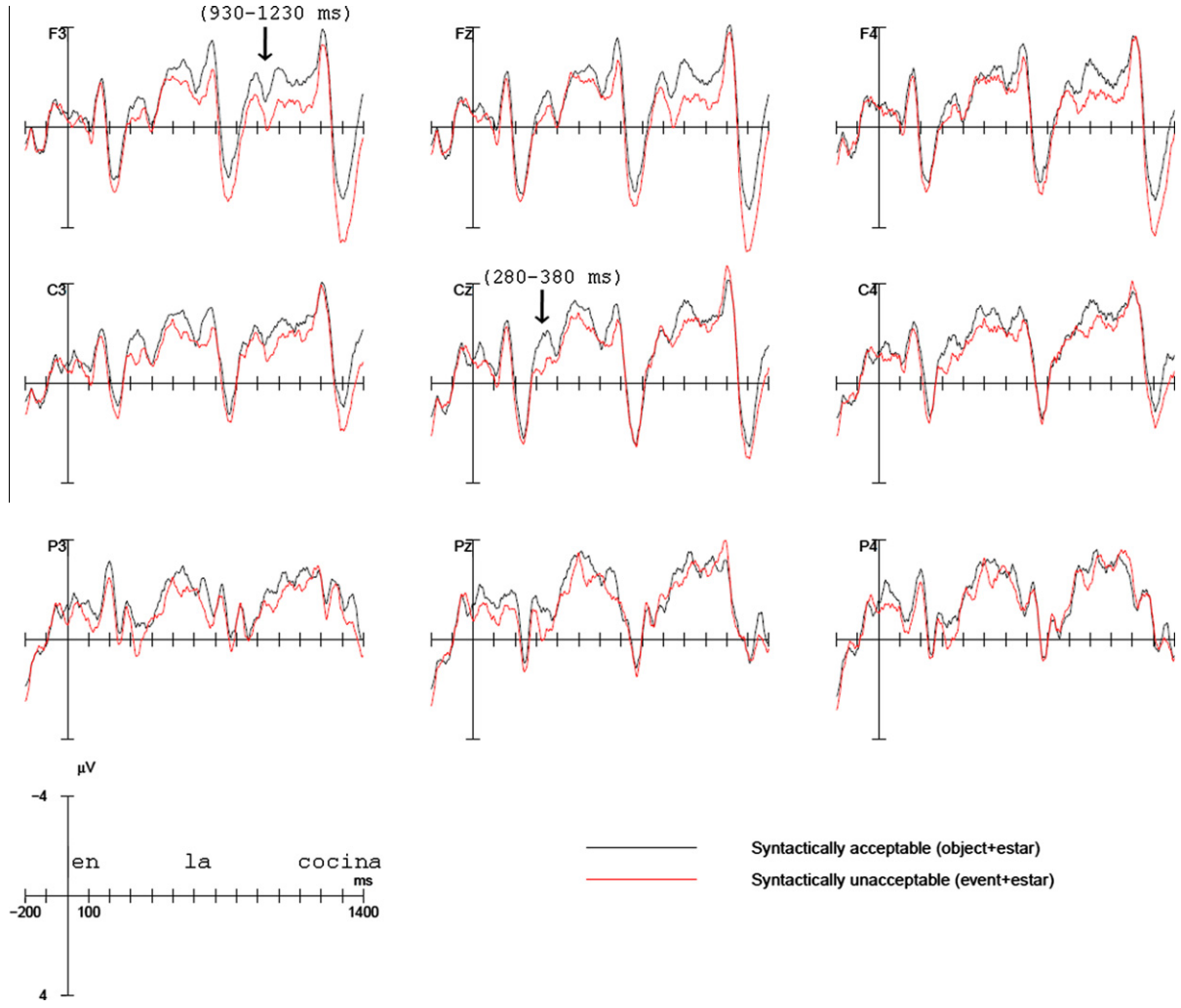

Fig. 2. Grand-averaged ERPs of the *estar en* predicate, time-locked to the *en* preposition. The black line refers to the syntactically acceptable combination (*estar en* headed by an object) and the red line refers to the syntactically unacceptable combination (*estar en* headed by an event). Negative values are plotted up.

topographical maps in Fig. 3 shows that while the differences between the *ser en* predicates show a posterior scalp distribution, the differences between the *estar en* predicates show an anterior distribution. In order to confirm these observations separate ANOVAs were performed for the *ser en* and the *estar en* sentences, and considering the different onset of the late positivities, two time windows were analyzed separately: 500–850 and 930–1230 ms after the preposition presentation. Additionally, the early positivity after the *estar en* combination was analyzed in a time window between 280 and 380 ms after the preposition onset.

3.2.1. Event vs. object + ser en

The ANOVA of the mean amplitude values corresponding to the 500–850 ms time window of the midline electrodes did not support significant differences. The ANOVA of the mean amplitude values of the lateral electrodes revealed a triple interaction between Syntactic acceptability, Hemisphere, and Region factors ($F(2, 58) = 7.245$, $p < .00$; 95% CI = ±3.24). Critically, in the post-hoc comparison, the analysis revealed a significant difference of the Syntactic acceptability factor only in the left posterior region (LP: mean difference between conditions = .60 μV; $t(29) = 2.32$, $p < .02$).

For the 930–1230 ms time window, the same ANOVA showed an interaction between Electrode and Syntactic acceptability ($F(2, 58) = 4.834$, $p < .02$; 95% CI = ±11.05). In the post-hoc comparison, we found a significant difference only at Pz (Pz: mean difference between conditions = −1.11 μV; $t(29) = -2.615$, $p < .01$). The ANOVA for the lateral sites yielded a triple interaction ($F(2, 58) = 7.638$, $p < .00$; 95% CI = ±3.29). Post-hoc comparisons showed a significant difference between the two conditions for the *ser en* construct only in the left parietal region (LP: mean difference between conditions = .58 μV; $t(29) = -2.355$, $p < .02$).

3.2.2. Object vs. event + estar en

The ANOVA of the mean amplitude values corresponding to the 280–380 ms time window of the midline electrodes showed a main effect of Syntactic acceptability ($F(1, 29) = 4.297$, $p < .04$). The ANOVA for the lateral electrodes with the factors Syntactic acceptability, Hemisphere and Region showed only a marginal effect of "Syntactic acceptability" ($F(1, 29) = 3.429$, $p < .07$).

The ANOVA of the mean amplitude values corresponding to the 930–1230 ms time window revealed an interaction between the Syntactic acceptability and Electrode factors ($F(2, 58) = 4.740$, $p < .03$; 95% CI = ±11.58). However, post-hoc comparisons showed that there was only a marginally significant effect for the Fz electrode (Fz: mean difference between conditions = .98 μV; $t(29) = 1.931$, $p < .06$). The ANOVA for the lateral electrodes yielded a triple interaction between the Syntactic acceptability, Hemisphere and Region factors ($F(2, 58) = 7.78$, $p < .00$; 95% CI = ±9.77). Post-hoc analyses revealed a significant difference of

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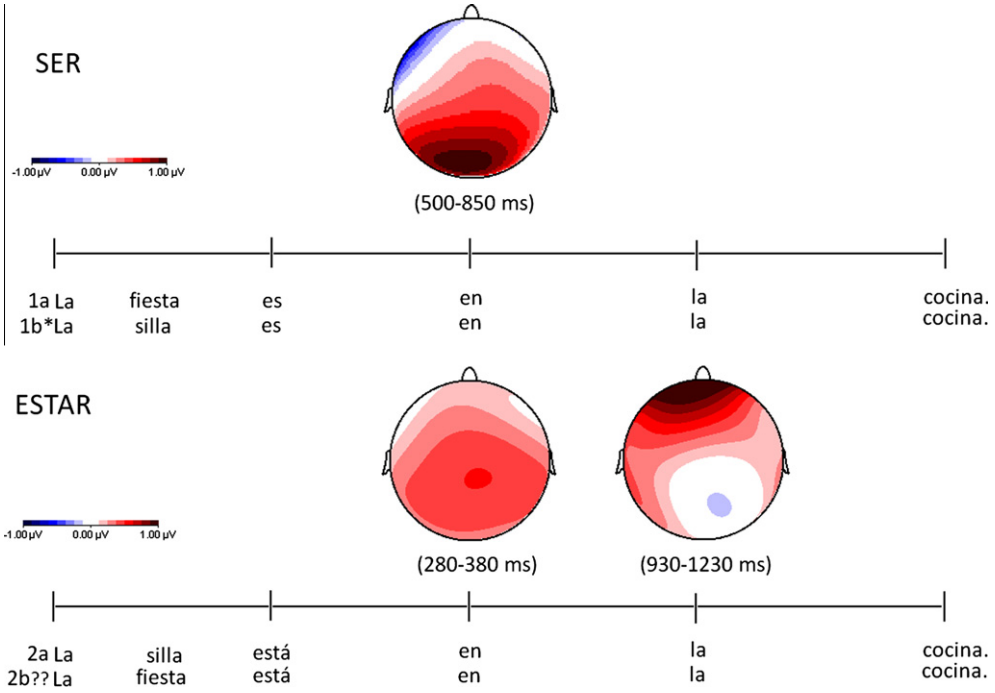

Fig. 3. Topographical distribution of the ERP effects for each experimental comparison: maps are calculated from the difference amplitude values (syntactically unacceptable minus syntactically acceptable combination) separately for *estar* (upper panel) and *ser* (lower panel). For *ser* the P600 effect elicited after the presentation of *en* is evident. In the lower panel, for *estar* the distribution of the first positivity in the 280–380 times window ms after the presentation of *en* and the distribution of the second one in the 930–1230 times window ms after the *en* presentation are evident. In the lower panel Maps refer to the average values of the amplitude differences in the time windows used for the statistical analyses.

Syntactic acceptability in the left anterior region (LA: mean difference between conditions = 1.08 μV; t (29) = 2.248, p < .03).

4. Discussion

In the current experiment we studied the different degrees of selectional restriction triggered by the combination of object/event semantic categories with *ser en* and *estar en* locative predicates in Spanish. Based on the data acquired from off-line questionnaires, we defined the use of the two forms of the verb "to be" in Spanish, sensitive to the semantic values of the subject nouns. We then tested these particular structures, recording the ERPs during sentence comprehension. Our results showed that subject-verb mismatch resulted in behavioral and electrophysiological effects which were different for *ser en* and *estar en* predicates.

The data from the correctness judgment task performed during the experiment are in line with the Sera et al. (1999) findings. While the object + *ser en* combination was judged incorrect, the event + *estar en* combination was considered acceptable. In both cases, participants were forced to make a dichotomic choice between judging a sentence to be correct and meaningful or incorrect and meaningless. However, our pre-test on grammaticality that gave participants the possibility to distinguish across a spectrum of syntactic acceptability from 1 to 7 showed that the event + *estar en* combination was also considered syntactically unacceptable although with a lesser degree of ungrammaticality than the object *ser en* combination. As we will see below, these findings are consistent with the ERP effects.

The use of a concrete object as subject noun with the *ser en* predicate, which was considered to be unacceptable both semantically and syntactically, resulted in a P600 effect after the reading of the preposition *en*. This P600 effect could represent a repair process after all the available information (pragmatic, syntactic, semantic) indicates sentence unacceptability to the cognitive system, but which could be understood if repaired (Bornkessel-Schlesewsky, & Schlesewsky, 2008; Friederici & Alter, 2004). In our study, the presence of P600 effects might be attributable to repair processes when the syntactic structure does not support any type of pragmatic interpretation, or when there is a mismatch between the processing pursued by the semantic and the syntactic combinatorial streams of processing (see Kuperberg, 2007). Indeed, the presence of the P600 indicates the syntactic unacceptability of the object + *ser en* combination. This interpretation is consistent with the syntactic implications of the individual/stage levels model (Kratzer, 1995), which proposes that the *ser en* locative predicate, at the individual level, cannot be associated with an object noun, as, for example, the location of a *chair* does not describe an inherent or defining property. In contrast, it is at odds with the Maienborn account (2005) that claims that only semantic–pragmatic information affects the interpretation of these predicates.

In addition, the *estar en* comparison revealed a centrally distributed positivity, starting around 280 ms after the presentation of the *en* preposition and lasting for 100 ms; with more positive amplitudes for the unacceptable event + *estar en* combination compared to the correct object + *estar en* combination. Further, after the presentation of the subsequent determiner *la* (the), the unacceptable combination was also associated to more positive amplitudes between 400 and 700 ms at frontal sites. We interpreted these positivities also as indexes of ongoing syntactic processing but showing a different time course of the repair/reanalysis processes than in the *object + ser en* combination. In the case of the object + *estar combination*, the "en" preposition triggers an initial positivity that could be interpreted as a P3-related component related to the detection of an unexpected structure or a potential anomaly. This first positivity was followed by a longer lasting positivity time-locked to the reading of the determiner "la", which would show the confirmation of the anomaly and the consequent

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repair/reanalysis operations. As the pre-test on the grammaticality revealed, there is a different degree of syntactic unacceptability between *ser en* and *estar en* predicates. While the object + *ser en* combination is unquestionably "wrong", the event + *estar en* combination could lead to a meaningful interpretation. This evidence is also consistent with Kratzer's hypothesis (1995) about stage-level predicates: *estar en* can be associated with an event that is taking place in a particular place, in contrary to *ser en* (individual-level predicate). Therefore, the *ser en* predicate with the object noun immediately revealed a strong P600 effect that we interpreted as a manifestation of the impossibility of interpretation at both syntactic and semantic/pragmatic levels and subsequent repair processing. In addition, the combination *estar en* with the event noun displayed two positive effects that might represent the initial detection of the "infrequent event", followed by a syntactic reanalysis of a structure that can be potentially interpretable. In this case, the utterance is in fact semantically acceptable, since the use of event + *estar en* to indicate a temporary event helps the syntactic parsing of the sentence. Therefore, we consider that, even if the syntactic processor is playing the most important role, semantic and pragmatic knowledge is also modulating the parsing operations and determining the different ERP responses to both types of anomaly.

This conclusion is in line with previous electrophysiological and neuroimaging evidence. Functional neuroimaging studies suggest that the brain regions engaged in the types of anomalies that evoke N400s are distinct from the regions engaged in the types of anomalies that evoke P600s in ERP studies (both outright semantic–pragmatic anomalies and syntactic violations). More specifically, semantic incongruities are associated with the recruitment of the left anterior inferior prefrontal cortex and/or the posterior superior and inferior temporal regions (Kuperberg et al., 2000, 2003), while syntactic anomalies are associated with activity within different sets of brain regions, usually much more anteriorly distributed (Friederici et al., 2004; Kuperberg et al., 2003; Newman, Pancheva, & Ozawa, 2001). However, these studies also show that some of the same regions that are activated to outright syntactic violations (Kuperberg et al., 2003) are also activated by the types of semantic violation that evoke P600s rather than N400s (Kuperberg et al., 2008). It is, therefore, becoming increasingly evident that semantic and syntactic processing are not encapsulated processes in the brain. In line with these findings, our study is further evidence that the syntactic and semantic streams dynamically interact with each other during language comprehension.

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