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Research Report

Are semantic and syntactic cues inducing the same processes in the identification of word order?

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Abstract

The purpose of this study was to find a common pattern of event-related potential (ERP) fluctuations regardless of the type of information (either semantic or syntactic) determining the presence of a reversed word order. ERPs were recorded while subjects read Spanish transitive sentences in which either semantic or syntactic information determined the actual word order. On the one hand (semantic condition), the order could be reversed by using an inanimate noun in the first noun phrase (NP), together with a verb representing an action that cannot correspond to an inanimate entity. On the other hand (syntactic condition), word order could be manipulated depending on the presence of a preposition preceding the second NP, which confirms the preferred word order, or a determiner, conveying a reversed word order. Interestingly, the inanimate first noun elicited a frontal negativity, which could be interpreted as the detection of an initial difficulty for using that noun as the subject of the sentence. At the point of disambiguation in either condition, a late posterior positivity was observed. The P600/SPS might, therefore, be an indicator of the syntactic processing costs incurred by the variation of word order, reflecting phrase structure reallocation processes common to this operation regardless of the cue used.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: ERP; Sentence parsing; Word order; Semantics; Syntax

1. Introduction

Event-related potentials (ERPs) have proved to be an efficient and highly useful tool in psycholinguistic research, particularly because they provide on-line evidence of language processing due to their high temporal resolution. Among the considerable possibilities in this regard, we should like here to take advantage of the relevance of this tool for the study of sentence processing.

Summarizing the main results, there appear to be several reliable ERP components appearing repeatedly during sentence processing. These components are basically: (a) a centro-parietal negativity starting at about 200 or 250 ms after word onset and peaking at about 400 ms, the N400; (b) anterior negativities different from the N400 but with similar latencies, even though they may appear much earlier; these are usually called LAN (Left Anterior Negativity, given its customary left fronto-central distribution) or ELAN (Early LAN, when they appear as early as between 100 and 200 ms); and (c) a later positivity called the P600 (or SPS, for Syntactic Positive Shift), usually displaying a posterior distribution.

When the type of variable manipulated is semantic, the N400 effect is the main finding [36]. Typically, this component is observed to words in a context (be this a sentence or even an isolated previous word), and seemingly correlates with the difficulty to integrate a word into that

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context [8–10,56]. In general, N400 amplitude seems to be directly related to the expectation of an item's presence in a given semantic context [28].

The anterior negativities and the posterior positivities usually appear in the syntactic domain. As mentioned above, anterior negativities have been typically labeled LAN or ELAN, depending on their onsets and latencies. Word-category violations are the anomalies most frequently associated with ELAN [1,16,23,25], whereas anterior negativities usually appearing later have been shown to be evoked by other grammatical anomalies, including (typically) morphosyntactic violations [22,26,42,43], but also by grammatically correct sentences with less commonly used constructions [39,52]. Even so, it is true that all of these types of violation have also failed to elicit anterior negativities in other studies [29,49,51]. Furthermore, neither the anterior distribution nor the left lateralization of these negativities are consistent findings (e.g., [11,23,27,42]). This component may reflect highly automatic first-pass parsing processes, the detection of a morphosyntactic mismatch and/or the inability to assign the incoming word to the current phrase structure [15,27], but it may also be related to working memory aspects of language processing [34,58].

As regards the second syntax-related component, the P600/SPS, it has also been found for syntactic violations [14,47], and to structurally ambiguous or garden path sentences [19,47]. With respect to its functional role, it has been suggested that the processes manifested by this late positivity are indicators of a greater syntactic processing cost due to a necessary revision and reanalysis of a structural mismatch, possibly also reflecting subsequent processes of repair when these are feasible [26, 30,44].

These ERP components of language processing have mostly been studied in sentences with some type of violation, that is, with incorrect material. Indeed, the number of studies focusing on correct material but of less frequent use is comparatively scarce. Within the research using correct material, we shall consider here a number of studies investigating the use of non-preferred word order by varying the most frequent or preferred order of the constituents of the sentence.

One of the clues speakers and readers use to identify grammatical functions within a sentence (such as subject and object), and, hence, the resulting relationships between them, is word order. The order in which words appear in the course of a sentence has strong implications for the way those words are processed. The listener/reader expects to receive linguistic information according to a preferred order by virtue of which one could assign grammatical roles to the incoming words in absence of other indicators. In this regard, we might mention here the 'Agent First' principle, according to which the agent appears preceding the focus or the object in a sentence. This principle is strongly present in second-language learners, 'home signs' invented by deaf children of non-signing parents, and in pidgin languages [6,21,35], thus revealing what Jackendoff [32,33] calls 'fossil principles' from protolanguage (i.e., a term introduced by Bickerton [5] to designate the precedents of modern human language). As a consequence of this 'fossil principle', the most common and preferred word order in most languages is SVO (subject–verb–object). The strength with which the listener/reader relies on word order is such that grammatical functions could be entirely determined by this feature. This is especially the case for languages such as English, in which grammatical markers are used to a lesser extent than in other languages, such as German. Despite this variability across languages with regard to its degree of relevance, however, word order is one of the clues used universally for grammatical function identification [4,37, 38,59]. In this sense, word order could be considered as a type of grammatical rule.

Accordingly, when a word-order preference is "violated", even if the sentence is grammatically correct, one might expect to find ERP fluctuations in relation to the syntax-related components. In fact, and in accordance with the consequences of applying the 'Agent First' principle, for example, when the parser detects that the initially appearing noun phrase (NP) is not the subject of the sentence, the disruption of an initially built structure would take place. Hence, anterior negativities (LAN) could be expected. Subsequently, a reanalysis and repair of the phrase structure would presumably be required, so that P600/SPS could also be predicted. However, it must be said that a review of the literature does not the clear assignment of specific ERP components to the process of detecting an anomalous word order. Detecting that the preferred word order is not the correct one may be achieved by virtue of either semantic or syntactic information, which provide the clues for determining the actual word order. In this regard, the ERP components involved when non-preferred structures have been studied appear to be not only heterogeneous but, remarkably, dependent on the type of information that disambiguates word order.

On the one hand, several studies have used syntactic features as the main cues in word-order variation. Relevant here are the numerous studies using garden-path sentences and other non-preferred structures (e.g., [17,28,39,47,52, 54]). These studies reported syntax-related ERP fluctuations, mainly P600/SPS, but also anterior negativities, when a variation of the preferred word order was detected during parsing. However, as mentioned, most of these studies have used syntactic cues to disambiguate word order, such as the number-marking information of the auxiliary [17] or case markers [39,52,59]. When, in contrast, semantic cues have been used, the results are rather different.

In this regard, Mecklinger et al. [41] presented relative clauses in sentences containing past participles in late positions that on grounds of semantic plausibility biased either a subject- or an object-relative reading. In fast comprehenders, larger N400 amplitudes appeared at the disambiguating point when there was a bias for object-relative reading rather than subject-relative reading.

Another study using semantic cues is that of Bornkessel et al. [7]. These authors manipulated the thematic structure of the verb in unambiguously case-marked German verb-final clauses, such that the processing of the verb either confirmed the preferred thematic ordering (active verbs) or required a reversal of this ordering (object-experiencer verbs). When, according to verb information, the order had to be reversed, an early parietal positivity between 300 and 600 ms was found. Given its early latency, this component was identified as the P345 described in the frame of previous studies [17,41], and probably belonging to the P600/SPS family, since it has been interpreted as reflecting a diagnosis of the need to structurally reanalyze the sentence [17]. However, at variance with those studies, Bornkessel et al. obtained the P345 using semantic cues, leading them to suggest that this component could be reflecting thematic reanalysis, thus dissociating it from the P600/SPS (see also [57]).

In the same line, other studies that did not approach the question of word order directly might in any case constitute evidence that using semantic or thematic information in competition with syntactic information regarding sentence structure can elicit semantic-related effects, such as the N400, which can nevertheless be accompanied by other, syntax-related ERPs. Frisch and Schlesewsky [18] studied German sentences with two arguments marked for nominative (two grammatical subjects), reporting a biphasic pattern of N400 and P600/SPS to the second argument when this was animate, but not when it was inanimate, in which case it showed only a P600/SPS. According to these authors, their results would demonstrate the use of the animacy (semantic) information to overcome problems due to thematic competition.

Weckerly and Kutas [58] presented two types of English object-relative sentences that varied in the use as subject of either an animate or an inanimate noun, the subject of the main clause always being of the contrary sign in this animacy dimension. That is, they had either an Animate (Inanimate) or an Inanimate (Animate) configuration. These authors found an N400 effect to the inanimate nouns used as subjects in main clauses, presumably revealing the reader's surprise at encountering an inanimate noun in the grammatical subject position, since subjects are typically animate. Among other findings, there was also a P600/SPS effect to the relative clause verb when the subject of this clause was inanimate, and both an anterior negativity (LAN) and a P600/SPS to the main clause verbs in the Animate (Inanimate) configuration, the latter case probably reflecting the greater difficulty in the processing of these sentences. Again, these findings would support the claim that semantic information has a substantial effect on the process of building the grammatical structure, and that when this occurs, semantic-related ERP effects can be found.

Accordingly, one could predict that varying structural preferences by virtue of either syntactic or semantic information would yield different results. When syntactic cues are used, syntax-related ERPs are found, indicating greater syntactic processing costs due to a necessary revision and reanalysis of a structural mismatch. When semantic cues are used, however, results are not unanimous. On some occasions, semantic-related ERPs have been reported, while in other cases, syntax-related ERPs, either alone or in combination with semantic-related ERPs, have been found. A component presumably reflecting thematic reanalysis has also been reported. Even so, the processes occurring after a non-preferred order is detected should be the same, regardless of the type of information used as cue. But the use of semantic information to vary word order has scarcely been studied, and there is a need for more research. Indeed, noticeable differences in the designs and materials might explain some of the reported differences, both between studies using semantic cues and between these studies and those using syntactic cues to determine word order. The present experiment was designed to further explore whether variations in word order result in specific changes of the ERPs regardless of the type of information determining word order.

The flexibility of Spanish allows the study of the processing of sentences that have syntactic variations without violating semantic constraints, and vice versa, while either syntactic or semantic variables determine the actual word order. In the present experiment, Spanish adults were asked to interpret simple sentences varying in word order, this word order being determined by either semantic cues or syntactic cues. On the one hand (semantic condition), the preferred SVO order could be reversed by using an inanimate name in the first NP, together with a verb representing an action that cannot correspond to an inanimate entity. Examples of these sentences are given in (1) and (2) with word-for-word translations into English and non-literal interpretation.

(1) SVO order:

El perro$_{\text{[Subject]}}$ saltó$_{\text{[Verb]}}$ la valla$_{\text{[Direct Object]}}$.
The dog$_{\text{[Subject]}}$ jumped$_{\text{[Verb]}}$ the fence$_{\text{[Direct Object]}}$ (=The dog jumped the fence.)

(2) OVS order:

La valla$_{\text{[Direct Object]}}$ saltó$_{\text{[Verb]}}$ el perro$_{\text{[Subject]}}$.
The fence$_{\text{[Direct Object]}}$ jumped$_{\text{[Verb]}}$ the dog$_{\text{[Subject]}}$. (=The fence was jumped by the dog.)

On the other hand (syntactic condition), word order could be manipulated depending on the presence of a contraction of a preposition and a determiner preceding the second NP, which determines SVO word order, or a determiner alone, conveying an OVS word order. Examples are given in (3) and (4) with word-for-word translations into English and non-literal interpretation.

(3) SVO order:

El poeta$_{[Subject]}$ desafió$_{[Verb]}$ al novelista$_{[Direct\ Object]}$.
The poet$_{[Subject]}$ challenged$_{[Verb]}$ the novelist$_{[Direct\ Object]}$.
(=The poet challenged the novelist.)

(4) OVS order:

El poeta$_{[Direct\ Object]}$ desafió$_{[Verb]}$ el novelista$_{[Subject]}$.
The poet$_{[Direct\ Object]}$ challenged$_{[Verb]}$ the novelist$_{[Subject]}$.
(=The poet was challenged by the novelist.)

Given that they are well equated in several variables– such as number of elements involved in each sentence, use of the Spanish language, transitivity of the sentences, their structure, and their simplicity–semantic and syntactic cues, even if different in nature, would imply similar psycholinguistic processes when reading these sentences. In both cases, a preferred SVO order can be reversed at a specific moment during sentence reading, and this would be followed by the disruption of an initially built phrase structure. Subsequently, a reanalysis of the phrase structure would be required. Accordingly, we expect to find some common modulations of brain activity related to presumably common functions.

2. Materials and methods

2.1. Participants

The experiment was conducted with 60 native Spanish speakers, of whom 46 were females, ranging in age from 19 to 25 years (mean = 21 years). All had normal or corrected-to-normal vision and were right-handed, with average handedness scores [46] of +72, ranging from +27 to +100. Subjects were paid for participating in this experiment.

2.2. Materials

There were 90 experimental items in the semantic condition and 90 experimental items in the syntactic condition, each describing simple transitive events. All sentences contained five words and had the same overall structure: a noun phrase followed by a verb and, finally, another noun phrase. All of them contained the same category sequence, [det]–[N]–[V]–[det]–[N], with the exception of the SVO version in the syntactic condition, in which the second determiner was substituted by the *contraction* of a preposition and a determiner (*al*, "to the"—this is a form used in Spanish only when the second noun is masculine). In both conditions, each sentence had two versions, i.e., either an SVO or an OVS word order.

In the semantic condition, the action represented by the verb can only be performed by an animate noun, which was placed behind the verb in the OVS version and preceding the verb in the SVO one. The other noun in these sentences was always an inanimate one. Therefore, in this condition, it is the semantic/thematic information contained in the verb that determines word order, that constitutes the disambiguating point, as participants also read sentences (fillers) in which an inanimate noun used as first NP is the subject of the sentence. Animate and inanimate nouns were of comparable familiarity (mean 76.1 for animate nouns, 66.9 for inanimate nouns; $t = -0.6$, $P > 0.1$) according to the Alameda and Cuetos [2] dictionary of frequencies for Spanish; nor did they differ in word length (6.1 and 6.7, respectively; $t = -1.1$, $P > 0.1$). In contrast, in the syntactic condition, the two nouns were animate. In this case, the point of disambiguation was the presence of a contraction of a preposition and a determiner, or a determiner alone, behind the verb, which indicated that the following noun was either the Direct Object or the Subject of the sentence, respectively. Although OVS versions in both conditions were of less frequent use (which, in any case, is inherent to non-preferred structures), in both cases, the sentences were always grammatically correct in Spanish [13]. Examples were given in the Introduction section, where (1) and (2) correspond to the SVO and OVS versions, respectively, of the semantic condition, and (3) and (4) to the SVO and OVS versions, respectively, of the syntactic condition. More examples are provided in Appendix A.

In addition to the experimental sentences, 50 fillers were included in each condition. These sentences were used primarily to reduce participants' expectations about where in the sentence the subject/agent was located. Thirty out of the 50 fillers were passive sentences constituted by seven words each, the first noun phrase always including an inanimate noun, and the second one an animate noun. These passive (filler) sentences were the same for both the semantic and the syntactic condition. Twenty out of the 50 fillers were simple sentences with the following structure: a noun phrase followed by the auxiliary verb *to be*, and, finally, a prepositional phrase. All these fillers had inanimate first NPs in the semantic condition so as to minimize as much as possible participants' anticipation of an inanimate noun in the first NP as direct object in the experimental materials. In the syntactic condition, however, both NPs in these simple filler sentences always included animate nouns. Additionally, and for both conditions, the verb *to be* was equated relative to its two meanings in Spanish (*ser* and *estar*), so that 10 sentences used one sense, and 10 sentences used the other.

All words were two to four syllables in length, with the exception of determiners and prepositions. Subjects' eyes were 65 cm from the screen. At that distance, a word composed of 6 letters was 1.14° high and 3.6° wide. Stimuli were presented white-on-black on an NEC computer

MultiSync monitor, controlled by the Gentask module of the STIM package (NeuroScan).

2.3. Procedure

Thirty participants were assigned randomly to the semantic condition and the remaining 30 to the syntactic condition. An experimental session consisted of 140 sentences, resulting from the randomized presentation of the critical materials and the fillers. Subjects also received a short training, consisting of the presentation of eight sentences of the type of the corresponding experimental materials, of which 4 followed an SVO and 4 an OVS order, as well as 6 fillers. None of the sentences used in the training were used as experimental materials.

All sentences appeared word-by-word in the center of a computer screen while the electroencephalogram was recorded. Each sentence was presented in the same form: the first word began with a capital letter and the last word was presented with a full-stop (period) at the end. Words were presented with a duration of 300 ms, with an interstimulus interval of 200 ms. Fig. 1 illustrates the stimulation paradigm.

Participants were instructed to read each word and try to link the words together in their minds in order to produce a comprehensible sentence, being advised that they had to report verbally which one of the two nouns was the subject, that is, the one that performed the action, after every sentence. Two seconds after onset of the last word in each sentence, there was a signal, indicating the moment at which participants had to make this report. Following their response, participants had to press a button to continue with the experiment. Subjects were encouraged to minimize blinking during sentence presentation and, rather, to confine blinks and movements to the period when they were giving their responses.

2.4. Electrophysiological recordings

An electrode cap (ElectroCap International) with tin electrodes was used for recording Electroencephalographic (EEG) data from a total of 58 scalp locations: Fp1, Fpz, Fp2, AF3, AF4, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FC5, FC3, FC1, FCz, FC2, FC4, FC6, T7, C5, C3, C1, Cz, C2, C4, C6, T8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, PO3, PO1, POz, PO2, PO4, PO8, O1, Oz, and O2. These labels correspond to the revised 10/20 International System [3], plus two additional electrodes, PO1 and PO2 located halfway between POz and PO3 and between POz and PO4, respectively. All scalp electrodes, as well as one electrode at the left mastoid (M1), were originally referenced to one electrode at the right mastoid (M2). The electrooculogram (EOG) was obtained from below versus above the left eye (vertical EOG) and the left versus right lateral orbital rim (horizontal EOG). Electrode impedances were always kept below 3 kΩ. The signals were recorded continuously with a band-pass between 0.01 and 50 Hz (3 dB points for −6 dB/octave roll-off) and were digitized at a sampling rate of 250 Hz.

2.5. Data analysis

For an overall view of the results, ERP waveforms across the whole sentence (3000 ms, plus 300 ms prior to the first word-stimulus, as a baseline) were first performed. Subsequently, ERP waveforms were made relative to the average activity in the 100 ms immediately preceding the onset of each word in the experimental sentences and ending 800 ms after that point. Additionally, two longer epochs were performed, each one relative to the average activity in the 100 ms immediately preceding the onset of the disambiguation point in each condition (the verb in the semantic condition; the preposition-plus-determiner contraction, or the determiner in the syntactic condition) and ending 1000 ms after the onset of the last word of the sentence. Only trials in which the question was answered correctly (correct trials) were used for the ERP averages.

Artifacts were automatically rejected by eliminating those epochs that exceeded ±65 μV (160 μV for across-sentence epochs). Additionally, a visual inspection was performed in order to eliminate epochs with too many blinks, excessive muscle activity, or other artifacts. Off-line

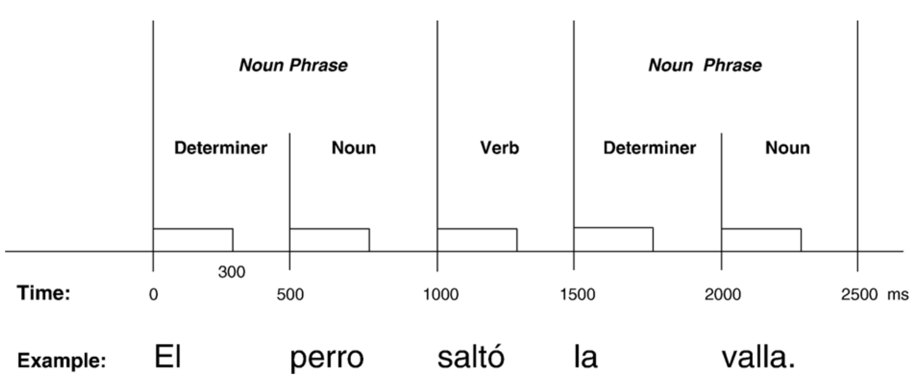

Fig. 1. Examples of the stimuli presented to subjects, together with a schematic representation of the stimulation procedures. In the SVO version of the syntactic condition, the second determiner was substituted by the contraction of a preposition and a determiner.

correction of smaller eye movement artifacts was also made, using the method described by Semlitsch et al. [55]. For the whole sample of cephalic electrodes, originally M2-referenced data were algebraically re-referenced off-line using the averaged mastoids as reference.

Overall repeated-measures analyses of variance (ANOVA) were first performed for amplitude comparisons. Amplitude was measured as the mean amplitude within a particular time interval. To avoid a loss of statistical power when repeated-measures ANOVAs are used to quantify a large number of electrodes [45], twelve regions of interest were computed out of 58 cephalic electrodes, each containing the mean of three or four electrodes (see Fig. 2). The regions were as follows: Region 1: left fronto-lateral (F7, F5, FC5); Region 2: left fronto-medial (F3, F1, FC3, FC1); Region 3: right fronto-medial (F2, F4, FC2, FC4); Region 4: right fronto-lateral (F6, F8, FC6); Region 5: left centro-lateral (T7, C5, TP7, CP5); Region 6: left centro-medial (C3, C1, CP3, CP1); Region 7: right centro-medial (C2, C4, CP2, CP4); Region 8: right centro-lateral (C6, T8, CP6, TP8); Region 9: left parieto-lateral (P7, P5, PO7); Region 10: left parieto-medial (P3, P1, PO3, PO1); Region 11: right parieto-medial (P2, P4, PO2, PO4); Region 12: right parieto-lateral (P6, P8, PO8).

ANOVAs were performed in the two conditions separately, and included two within-subjects factors: sentence type (two levels: SVO, OVS) and region of interest (12 levels). Only the results in which the sentence type factor, alone or in interaction, was found to be significant will be considered of interest. The Greenhouse–Geisser correction was always applied. Time windows were chosen on the basis of a visual inspection of the data. Finally, statistical post hoc analyses with the Bonferroni correction comparing each sentence type were conducted for each particular region of interest wherever appropriate.

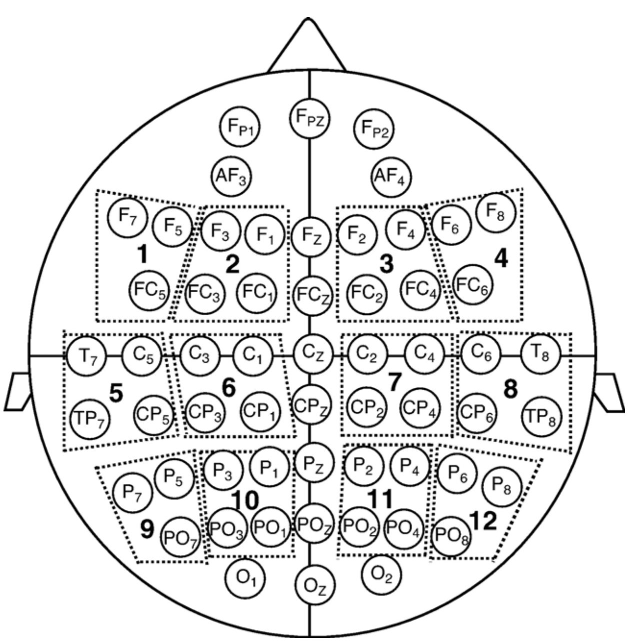

Fig. 2. Layout of the 12 regions of interest in relation to the measured electrodes.

Finally, and given their relevance for the present study, the distributions of the posterior positivities accompanying OVS orders in either condition were further explored and compared both within and between conditions. For these purposes, Profile Analyses [40] were performed, which assess differences in scalp topographies independent of overall ERP amplitude. For the corresponding time windows, mean amplitudes were scaled for each subject across all electrodes, with the average distance from the mean, calculated from the grand mean ERPs, as denominator. Significant differences in ANOVAs with these scaled data, where possible effects of source strength are eliminated, indicate different scalp distributions [53]. For these analyses, the whole array of 58 electrodes was used, as this is a better procedure for profile analyses, and previous ANOVAs using unscaled data were also performed. Furthermore, as these comparisons were centered on the posterior positivities accompanying OVS orders, the data used for these analyses were the result of subtracting the mean amplitude in the SOV orders from that in the OVS orders. ANOVAs with both unscaled and scaled data were of two types. For within-condition comparisons, they included two within-subjects factors: time window and electrode (58 levels). For between-conditions comparisons, they included a within-subjects factor (electrode, 58 levels) and a between-subjects factor (condition: semantic or syntactic).

3. Results

3.1. Performance data

On average, participants responded incorrectly to 2% (range 0–4) of the SVO sentences and 4% (0–5) of the OVS sentences in the semantic condition, these values being 7% (0–12) and 5% (0–11), respectively, in the syntactic condition. Overall, subjects had no difficulty responding, and appear to profit from the task, indicating that they were attending to the materials and performed the tasks properly.

3.2. Electrophysiology

3.2.1. Across-sentence ERPs

An overview of the main results can be seen in Fig. 3. In either condition, the preferred SVO and the non-preferred OVS orders display similar activity until late during sentence processing. Roughly after the corresponding disambiguating point (the third word in the semantic condition; the fourth word in the syntactic condition), a posterior positivity develops for OVS order, this positivity turning to frontal positions at the very end of the recording epoch. In addition, a negativity for OVS sentences appears after the first noun (the second word) in the semantic

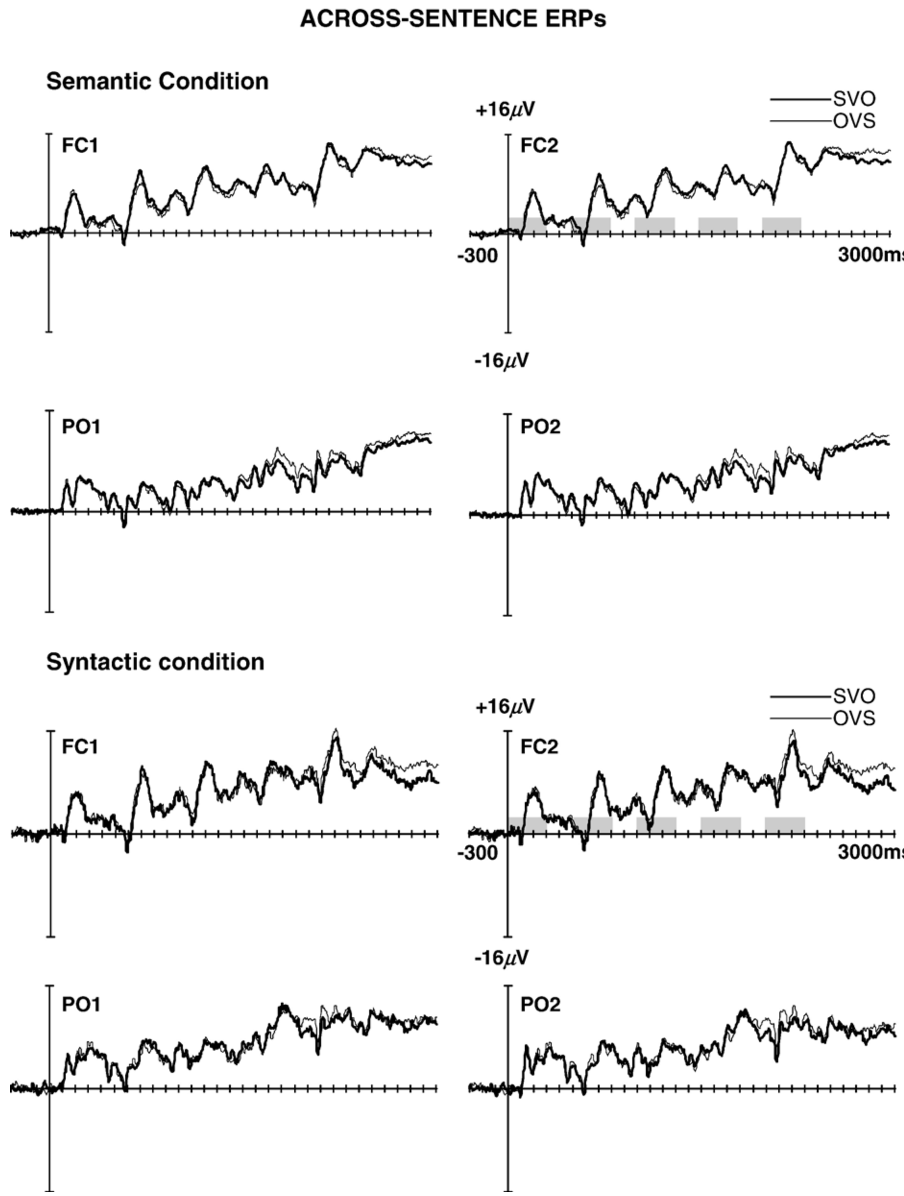

Fig. 3. Grand average ERP (n = 30) time-locked to the onset of the first word and covering the whole sentence for SVO (preferred word order) and OVS orders in the semantic condition (top) and in the syntactic condition (bottom). Note that for this and subsequent figures, only a selection of electrodes is displayed.

condition. These results are analyzed and described in detail in the following sections.

3.2.2. Single-word ERPs

3.2.2.1. Semantic condition. As mentioned above, differences between SVO and OVS sentences in the semantic condition began to appear in the ERP corresponding to the second word in the sentences (the first noun). This difference would probably relate to the animacy dimension, as OVS sentences in this condition used an inanimate noun in the first NP of the sentence. Inanimate nouns displayed a frontal negativity at about 200 ms after stimulus onset. An ANOVA was performed in the 160–240 ms window, revealing a significant effect of sentence type ($F_{1,29}$ = 4.9; P < 0.05) and a trend for significance in the sentence type × region of interest interaction $F_{11,319}$ = 2.9; P < 0.1). Post hoc analyses revealed a significant difference between SVO and OVS sentences at the left fronto-lateral region (region 1) (t = 3.1; P < 0.05 after Bonferroni correction). This difference can be appreciated in Fig. 4, which includes a map with the distribution of the effect.

In the following (third) word, corresponding to the verb of the sentence (i.e., the disambiguation point in this condition), a parietal positivity was observed for OVS sentences, starting at about 500 ms after stimulus onset and lasting until the end of the recording epoch. This positivity exhibited a similar distribution across this period. An ANOVA performed in the 500–700 ms window revealed a significant sentence type × region of interest interaction

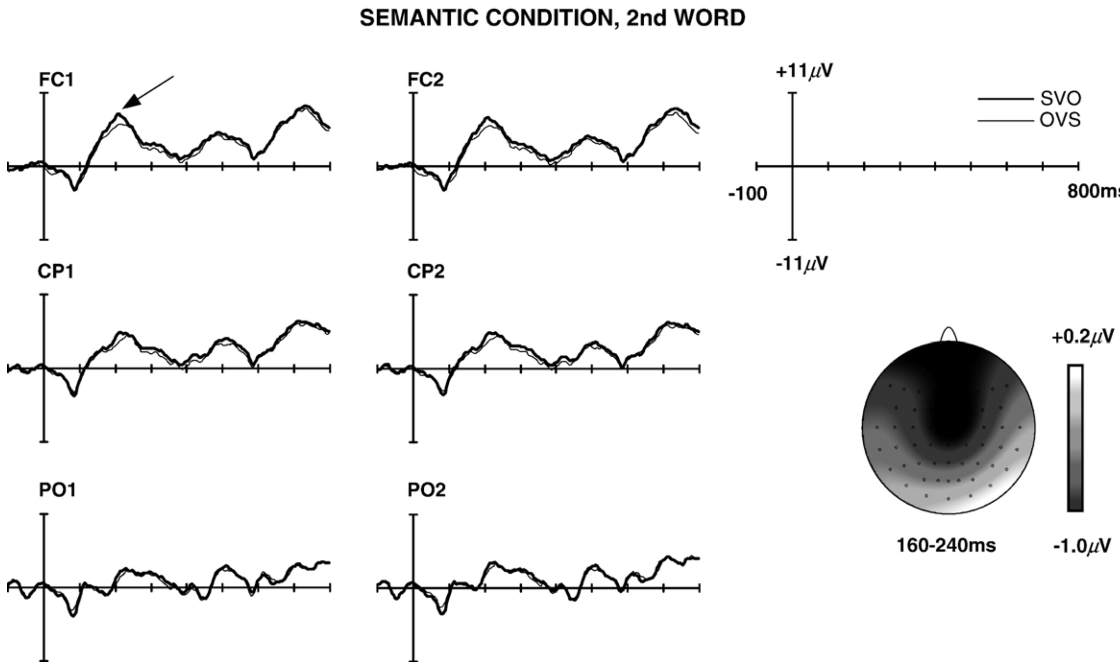

Fig. 4. Grand average ERP time-locked to the onset of the first noun of SVO and OVS orders in the semantic condition. This noun referred to an animate entity in the SVO sentences and to an inanimate entity in OVS material. For the latter, a negativity at about 200 ms over frontal locations was observed. The map displays this negativity, computed from the mean amplitude in the 160–240 ms time window of the OVS minus SVO difference wave. The map scale is based on the particular maximum and minimum values found for that window. This and subsequent maps are interpolated with spherical splines, using the algorithm described in [50].

$F_{11,319} = 6.7$; $P < 0.001$), while post hoc analyses revealed significant differences between SVO and OVS sentences at the left parieto-medial region (region 10) ($t = -3.7$; $P < 0.05$) and the right parieto-medial region (region 11) ($t = -3.3$; $P < 0.05$). This result can be seen in Fig. 5, which includes a map with the distribution of the parietal positivity.

The second determiner (fourth word) revealed a long-lasting parietal positivity in the OVS sentences. This positivity appears to be a continuation of the effects

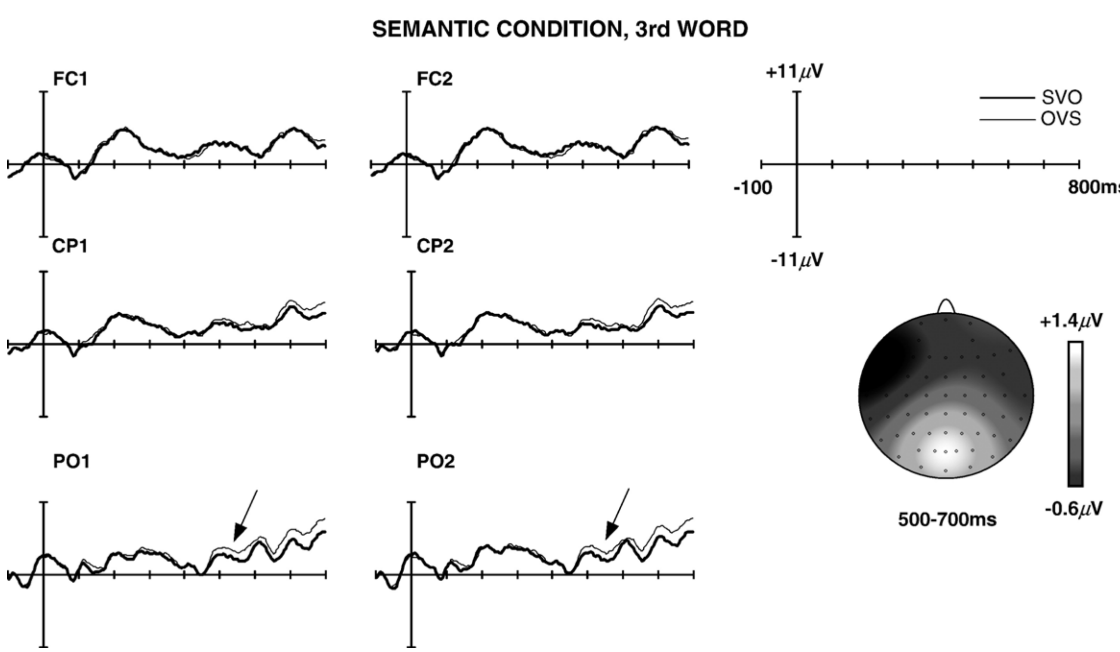

Fig. 5. Grand average ERP time-locked to the onset of the verb of SVO and OVS orders in the semantic condition. This verb represents an action that cannot correspond to a preceding inanimate entity in OVS sentences. A positivity over posterior locations was observed in OVS sentences, starting at about 500 ms after onset of the stimulus. The map displays this positivity, computed from the mean amplitude in the 500–700 ms time window of the OVS minus SVO difference wave. The map scale is based on the particular maximum and minimum values found for that window.

described for the previous word. It is best seen between about 100 and 500 ms after stimulus onset, though it does extend beyond this time range. Given its long duration, three time windows were selected to perform the ANOVA. In the 100–300 ms window, a significant sentence type × region of interest interaction was found $F_{11,319}$ = 3.9; P < 0.05), as well as a significant effect of sentence type alone $F_{1,29}$ = 6.3; P < 0.01), while post hoc analyses revealed significant differences between SVO and OVS sentences at the left parieto-lateral region (region 9) (t = −4.4; P < 0.01), the left parieto-medial region (region 10) (t = −4.2; P < 0.01), the right parieto-medial region (region 11) (t = −3.5; P < 0.05), and the right parieto-lateral region (region 12) (t = −3.6; P < 0.05). In the 300–500 ms window, there was also a significant sentence type × region of interest interaction $F_{11,319}$ = 3.7; P < 0.05) and a significant effect of sentence type alone $F_{1,29}$ = 22.2; P < 0.01), post hoc analyses revealing significant differences between SVO and OVS sentences at the left centro-lateral region (region 5) (t = −4.4; P < 0.01), the left centro-medial region (region 6) (t = −4.2; P < 0.01), the right centro-medial region (region 7) (t = −3.9; P < 0.01), the left parieto-lateral region (region 9) (t = −4.4; P < 0.01), the left parieto-medial region (region 10) (t = −6.7; P < 0.01), the right parieto-medial region (region 11) (t = −4.5; P < 0.01), and the right parieto-lateral region (region 12) (t = −3.7; P < 0.01). In the 500–700 ms window, there was a significant effect of sentence type alone $F_{1,29}$ = 7.3; P < 0.05), post hoc analyses yielding significant differences between SVO and OVS sentences at the left centro-lateral region (region 5) (t = −3.3; P < 0.01) and the left parieto-lateral region (region 9) (t = −3.1; P < 0.05). The long-lasting positivity for the second determiner of the OVS sentences can be appreciated in Fig. 6.

The fifth and final word (the second noun) revealed a long-lasting parieto-medial negativity in the OVS material. This negativity started at about 100 ms after stimulus onset and lasted until the end of the recording epoch, though it became more visible from about 250 ms. Given its long duration, three consecutive time windows were selected to perform the ANOVA. In the 100–300 ms window, a significant effect of sentence type was found $F_{1,29}$ = 4.4; P < 0.05), but post hoc analyses did not yield any significant difference between SVO and OVS sentences after Bonferroni correction. In the 300–500 ms window, a significant sentence type × region of interest interaction was found $F_{11,319}$ = 3.8; P < 0.05), as well as a significant effect of sentence type alone $F_{1,29}$ = 4.9; P < 0.05), while post hoc analyses revealed only a trend for significance in the differences between SVO and OVS sentences at the right parieto-medial region (region 11) (t = 3; P < 0.1). In the 500–700 ms window, there was a significant sentence type × region of interest interaction $F_{11,319}$ = 8.8; P < 0.001), and post hoc analyses revealed a significant difference between SVO and OVS sentences at the right parieto-medial region (region 11) (t = 3.1; P < 0.05). The long-lasting negativity for the second noun of the OVS sentences can be appreciated in Fig. 7. Only the maps for the time windows in which a trend for significance or a significant result was obtained in

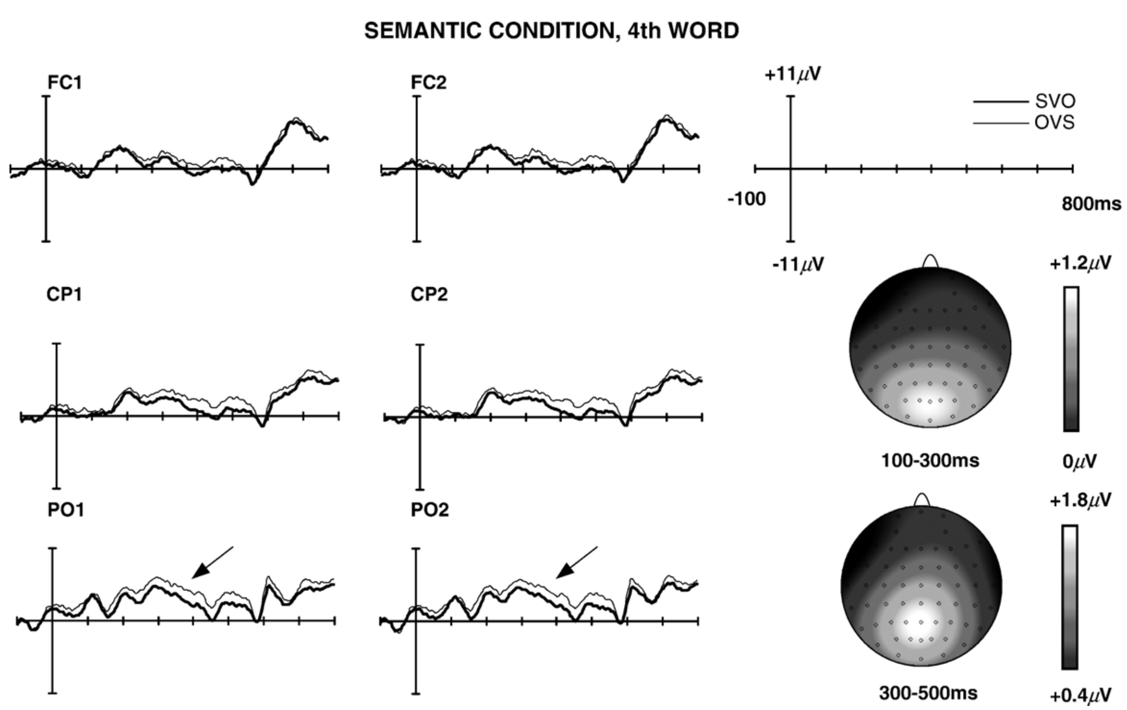

Fig. 6. Grand average ERP time-locked to the onset of the second determiner of SVO and OVS orders in the semantic condition. A long-lasting positivity over posterior locations was observed in OVS sentences, which was best seen between about 100 and 500 ms after stimulus onset. Two maps were computed from the mean amplitude in the 100–300 and 300–500 ms time windows of the OVS minus SVO difference wave, revealing that the distribution of this positivity did not substantially change across time. The map scales are based on the particular maximum and minimum values found for each window.

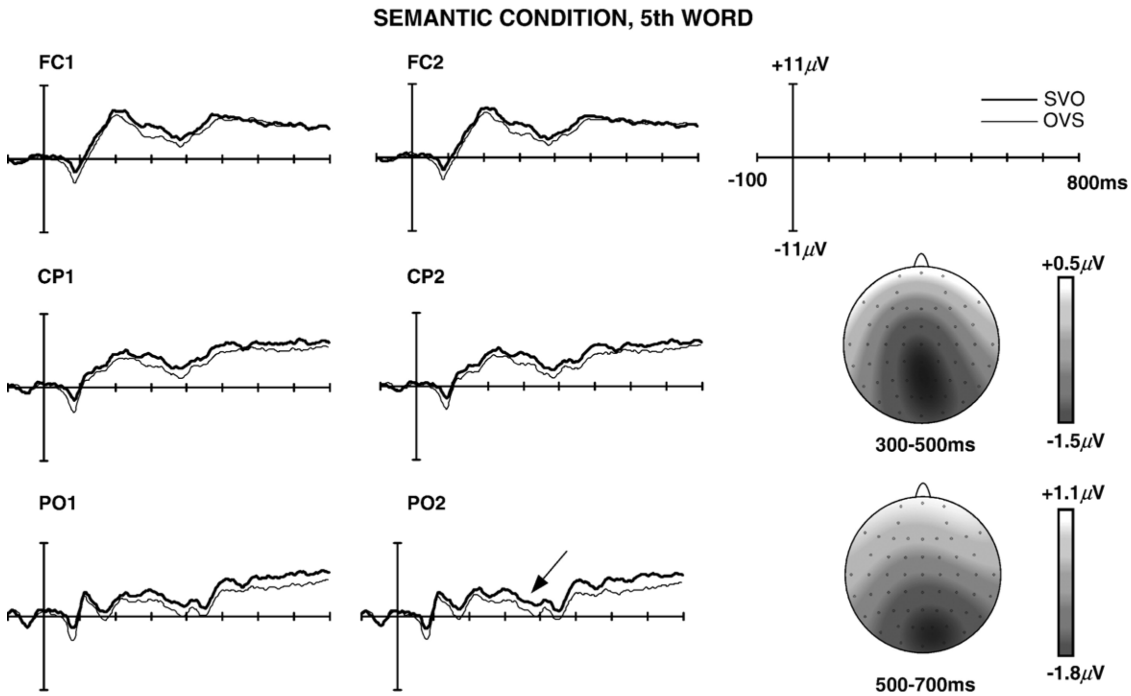

Fig. 7. Grand average ERP time-locked to the onset of the second noun (last word) of SVO and OVS orders in the semantic condition. A long-lasting parieto-medial negativity appeared in the OVS material, this negativity starting at about 100 ms after stimulus onset and continuing until the end of the recording epoch. Given its long duration, three time windows were used in the analyses, but only the later two yielded significant post hoc results. The two maps correspond to these windows, and were computed from the mean amplitude in the 300–500 and 500–700 ms time windows of the OVS minus SVO difference wave. Again, the distribution of this positivity did not substantially change across time. The map scales are based on the particular maximum and minimum values found for each window.

the post hoc analyses are displayed, though the distribution was rather similar across the three time intervals.

3.2.2.2. Syntactic condition. Differences between SVO and OVS sentences in the syntactic condition began to appear in the ERP corresponding to the fourth word in the sentences (the preposition-determiner contraction in the SVO sentences, the determiner in the OVS sentences), which was actually the point at which a word-order reversal is indicated in this condition. At this point, a positivity between about 450 ms and 700 ms after stimulus onset was observed for OVS sentences. Fig. 8 shows the waveforms and the distribution of this effect. As can be seen, it displayed parieto-medial distribution, mainly over the left hemisphere. An ANOVA performed in the 500–700 ms window revealed a significant sentence type × region of interest interaction $F_{11,319} = 5.3$; $P < 0.01$) and a significant effect of sentence type alone $F_{1,29} = 5.2$; $P < 0.05$). Post hoc analyses revealed significant differences between SVO and VOS sentences at the left parieto-lateral region (region 9) ($t = -3.6$; $P < 0.05$) and the left parieto-medial region (region 10) ($t = -3.3$; $P < 0.05$), and a trend for significance at the left centro-lateral region (region 5) ($t = -3.1$; $P < 0.1$).

Results corresponding to the final word in the sentence in the syntactic condition (not shown) did not indicate any noticeable difference between SVO and OVS sentences. As described elsewhere, observable differences in brain activity at this time period indeed began before onset of this last word, so that through the use of a pre-stimulus baseline based on this onset, these differences seemed to disappear.

3.2.2.3. Long epoch following the disambiguation point. Apart from the fluctuations to single words in the sentences, a longer epoch was analyzed starting 100 ms before the onset of the disambiguation point in either condition, and ending 1000 ms after onset of the final word of each type of sentence. This point corresponds to the verb in the semantic condition, and to the preposition/determiner contraction (SVO version) or the second determiner (OVS version) in the syntactic condition. Results corresponding to the semantic condition can be seen in Fig. 9. There, it can be appreciated that the positivity that began with the appearance of the verb in OVS sentences seems to continue beyond the appearance of the following word (the determiner in the second NP), being progressively substituted by a positivity at frontal locations, mainly right. Three consecutive time windows were selected to perform ANOVA calculations, extending the results obtained for the epoch corresponding to the verb alone. In the 800–1000 ms window (corresponding to 300–500 ms after onset of the second determiner), significant effects of sentence type $F_{1,29} = 7.6$; $P < 0.01$) and of sentence type × region of interest interaction $F_{11,319} = 14.9$; $P < 0.0001$) were found. Post hoc analyses revealed significant differences between

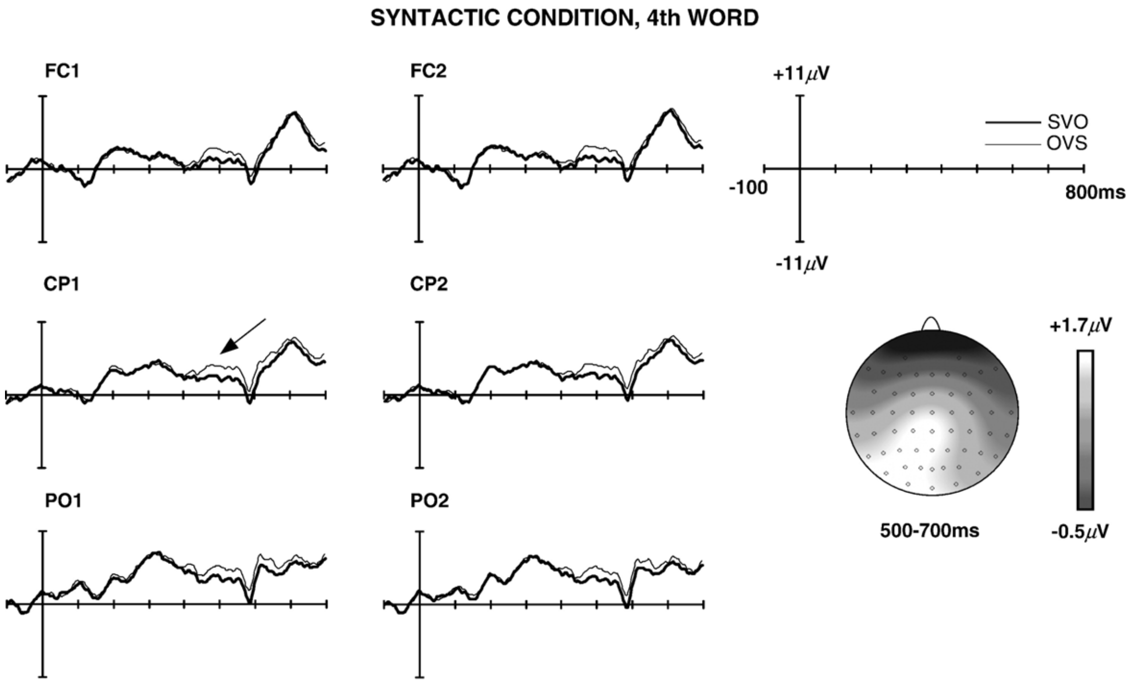

Fig. 8. Grand average ERP time-locked to the onset of the disambiguation point (the preposition-determiner contraction in the SVO sentences, the determiner in the OVS sentences) of SVO and OVS orders in the syntactic condition. A positivity over posterior locations was observed in OVS sentences, starting at about 450 ms after onset of the stimulus. The map displays this positivity, computed from the mean amplitude in the 500–700 ms time window of the OVS minus SVO difference wave. The map scale is based on the particular maximum and minimum values found for that window.

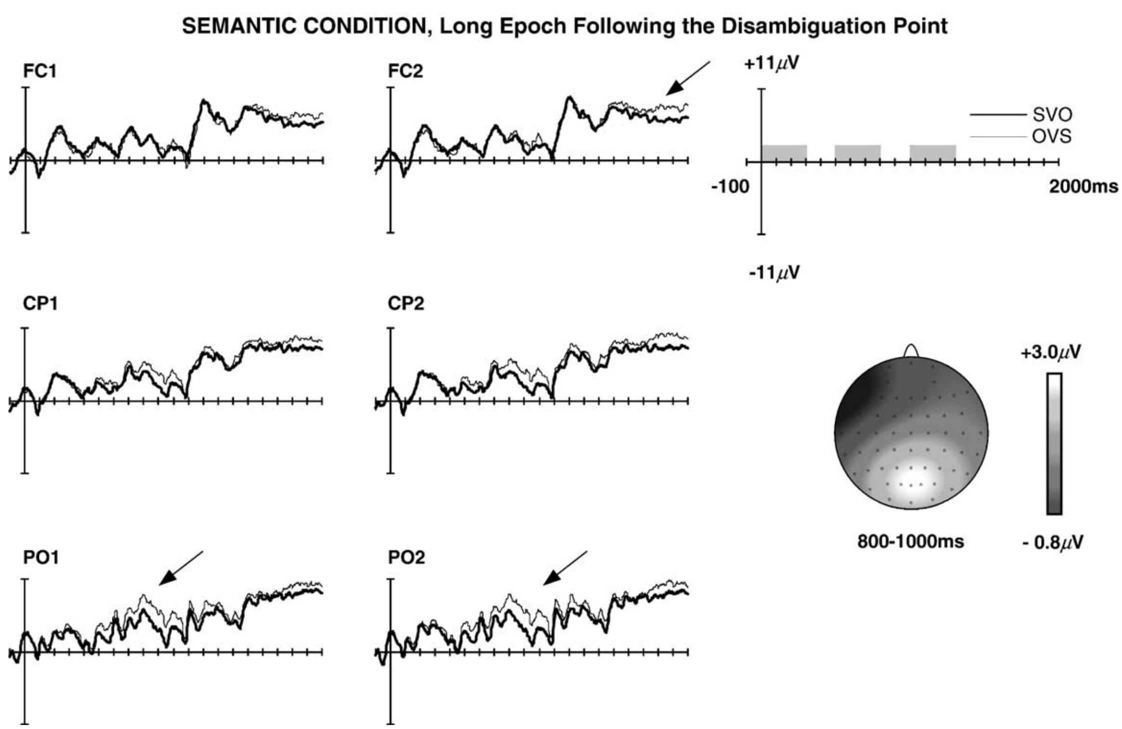

Fig. 9. Grand average ERP using a long epoch, time-locked to the onset of the disambiguation point (the verb) of SVO and OVS orders in the semantic condition, extending beyond the appearance of subsequent elements (second determiner and second noun). The positivity that started with the verb in OVS sentences continues beyond the appearance of the following word, being progressively substituted by a positivity at frontal locations. Three time windows were used in the analyses, but only the first one (800–1000 ms) yielded significant post hoc results. The map corresponds to this window, and is computed from the mean amplitude in that interval of the OVS minus SVO difference wave. The map scale is based on the particular maximum and minimum values found for that window.

SVO and OVS sentences at the right centro-medial region (region 7) (t = −3.5; P < 0.05), the left parieto-lateral region (region 9) (t = −4.2; P < 0.01), the left parieto-medial region (region 10) (t = −5.4; P < 0.01), the right parieto-medial region (region 11) (t = −5.7; P < 0.01), and the right parieto-lateral region (region 12) (t = −5.6; P < 0.01). In the 1200–1400 ms window (corresponding to 200–400 ms after onset of the second noun), significant effects of sentence type × region of interest interaction $F_{11,319}$ = 3.4; P < 0.05) were found. However, post hoc analyses did not yield any significant result after Bonferroni correction. This was also the case for the 1600–1800 ms window (that is, 600–800 ms after onset of the second noun), despite a significant sentence type effect $F_{1,29}$ = 5.2; P < 0.05) in the overall ANOVA. Accordingly, Fig. 9 only includes the map for the 800–1000 ms window.

Results corresponding to the syntactic condition can be seen in Fig. 10. On consideration of this figure, it can be appreciated that the positivity which started with the appearance of the second determiner in OVS sentences seems to continue slightly beyond the appearance of the final word (the second noun), though a frontal positivity emerges at this point, extending until the end of the epoch. Two consecutive time windows were selected to perform ANOVA calculations, extending the results obtained for the epoch corresponding to the fourth word alone. In the 800–1000 ms window (corresponding to 300–500 ms after onset of the second noun), only a trend for significance was found for sentence type $F_{1,29}$ = 3.8; P < 0.1), and post hoc analyses did not yield any significant result after Bonferroni correction. In the 1200–1400 ms window (700–900 ms after onset of the second noun), despite a significant sentence type effect $F_{1,29}$ = 4.9; P < 0.05) in the overall ANOVA, post hoc analyses did not yield any significant result after Bonferroni correction. Accordingly, Fig. 10 only includes the ERP waveforms.

For the purposes of the present study, the posterior positivities that followed the disambiguation point in either condition were considered of the greatest interest. Therefore, more detailed analyses of these positivities were performed in order to attain a better description of their time course and topography, as well as to compare the semantic and syntactic conditions in these parameters. These analyses were based on the long epochs following the disambiguation point (Figs. 9 and 10). First, topographic maps for narrower (i.e., 100 ms wide) consecutive windows were performed, computed from the mean amplitude of the OVS minus SVO sentences and covering the period to the corresponding rise-to-fall of the posterior positivity in each condition. This can be seen in Fig. 11. As can be appreciated, the posterior positivity in the semantic condition did not substantially change across time, yielding a parieto-medial distribution with a negative

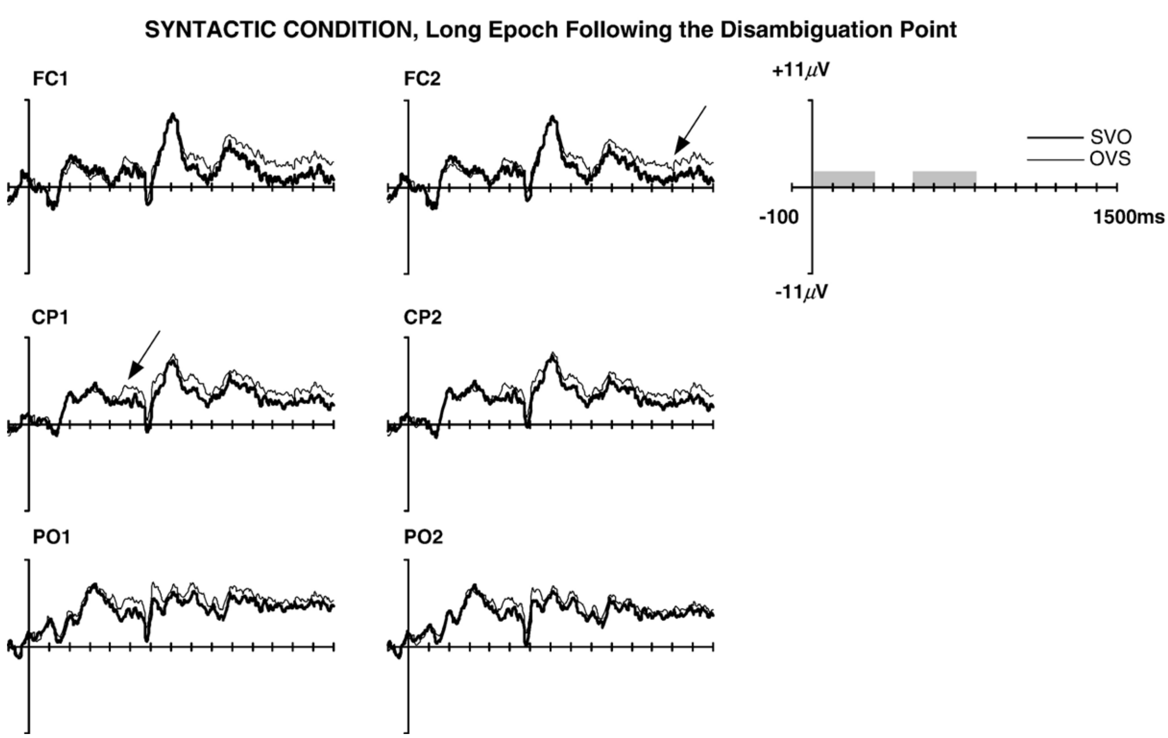

Fig. 10. Grand average ERP using a long epoch, time-locked to the onset of the disambiguation point (the preposition-determiner contraction in the SVO sentences, the determiner in the OVS sentences) of SVO and OVS orders in the syntactic condition, extending beyond the appearance of the subsequent element (the second noun). The positivity that started with the determiner in OVS sentences continues slightly beyond the appearance of the following word, being progressively substituted by a positivity at frontal locations. Two time windows were used in the analyses, the first (800–1000 ms) yielding only a trend for significance in the overall ANOVA and the second (1200–1400 ms) yielding no significant post hoc results. Consequently, no map is displayed in this figure.

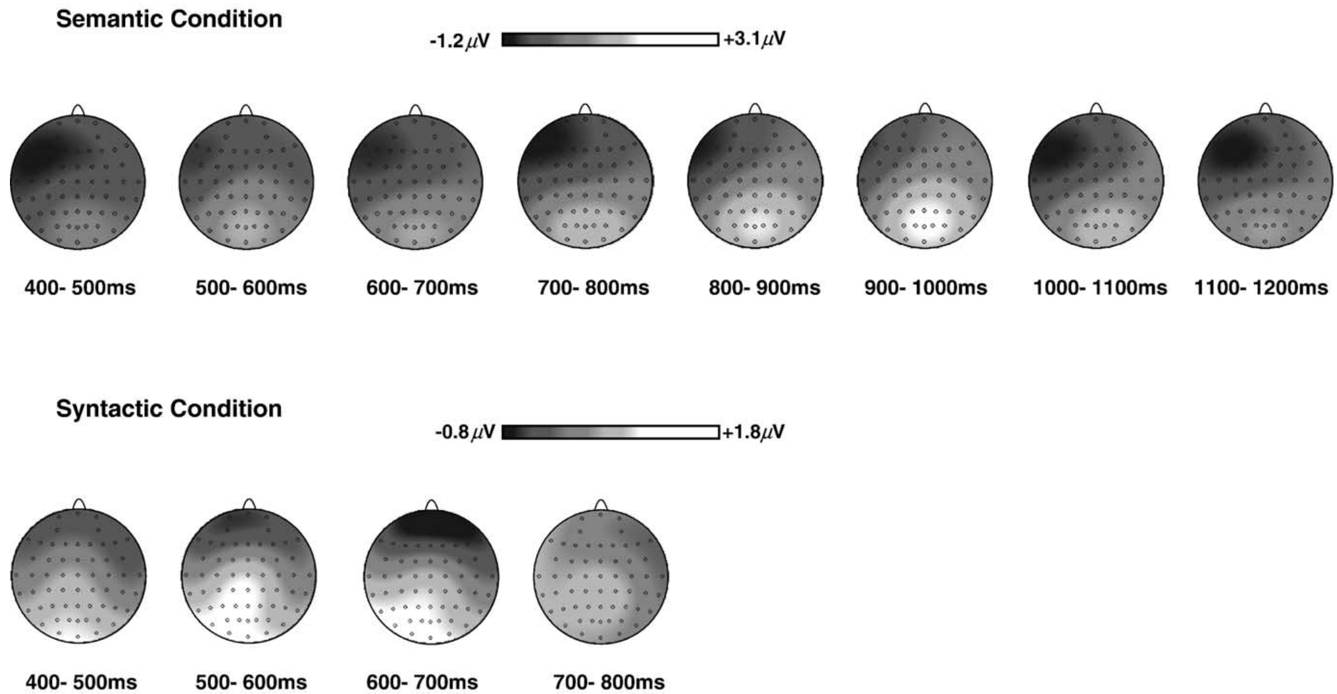

Fig. 11. Maps displaying the posterior positivity following the disambiguation point in each condition, computed from the mean amplitude of the OVS minus SVO sentences (data displayed in Figs. 9 and 10). They are based on 100-ms-wide windows covering the period to the corresponding rise-to-fall of the posterior positivity in the semantic (top) and syntactic (bottom) conditions. The map scales are based on the particular maximum and minimum values found for each condition.

counterpart of much smaller amplitude over left anterior locations. In this condition, the posterior positivity displayed a long duration, increasing gradually from its onset and reaching its highest values in the 900–1000 ms window. After this, the positivity resolves promptly. This confirms our previous assertion that the main results for the second determiner in the semantic condition are in fact a continuation of the effects that began after the appearance of the verb.

As regards the posterior positivity in the syntactic condition, it seemed to display a non-identical distribution across time, though the differences were indeed not particularly remarkable. In this condition, the posterior positivity was of shorter duration, and whereas in a first period (500–600 ms) it seemed to distribute more centrally, it was subsequently (600–700 ms) more posterior. In both cases, a frontal counterpart, now rather bilateral, could also be observed.

For topographic comparisons of these positivities, we selected the 900–1000 ms window from the semantic condition and the 500–600 and 600–700 ms windows from the syntactic condition. It seemed redundant to make a topographic comparison within the semantic condition. Comparing the two windows in the syntactic condition using unscaled data did not yield significant effects either for window $F_{1,29}$ = 0.06; $P > 0.1$) or for the window by electrode interaction $F_{57,1653}$ = 0.4; $P > 0.1$). This result would indicate that the posterior positivity in the syntactic condition did not differ either in amplitude or in topography across these two time windows. The use of scaled data (profile analyses) confirmed the latter assertion (window by electrode interaction: $F_{57,1653}$ = 0.3; $P > 0.1$). The 900–1000 ms window in the semantic condition was compared to each of the two windows in the syntactic condition separately. When compared to the 500–600 ms window using unscaled data, no significant effects were found either for condition $F_{1,29}$ = 0.3; $P > 0.1$) or for the condition by electrode interaction $F_{57,1653}$ = 1.4; $P > 0.1$). This result would indicate that the posterior positivity did not differ between conditions either in amplitude or in topography when the 500–600 time window was selected in the syntactic condition. Profile analyses confirmed the latter assertion (condition by electrode interaction: $F_{57,1653}$ = 0.7; $P > 0.1$). Finally, when the positivity in the semantic condition was compared to the 600–700 ms window in the syntactic condition using unscaled data, no significant effects were found either for condition $F_{1,29}$ = 0.9; $P > 0.1$) or for the condition by electrode interaction $F_{57,1653}$ = 1.5; $P > 0.1$). This result would indicate that the posterior positivity did not significantly differ between conditions, either in amplitude or in topography, when the 600–700 time window was selected in the syntactic condition. Profile analyses confirmed the latter assertion (condition by electrode interaction: $F_{57,1653}$ = 1.2; $P > 0.1$).

4. Discussion

The purpose of this study was to explore whether variations in word order result in specific ERP fluctuations regardless of the type of information determining word order. It would appear that we have been at least partially successful in this goal, as parietal positivities probably reflecting reanalysis or repair processes have been found regardless of the type of cue used. Also, we were able to find a LAN effect when the cue determining word order was semantic information.

The first result to appear in time actually corresponds to a frontal negativity, presumably of the LAN type, obtained to the first noun in the OVS version in the semantic condition. The latency at which our anterior negativity appeared (about 200 ms) was rather early, being indeed more characteristic of an ELAN than of a LAN. However, whereas the former is observed for word-category violations, the latter is most often observed for the many other types of syntactic anomalies, within which our materials would more properly be included. It is true, however, that variable latencies have been described for LAN effects, some studies reporting latencies exceeding the upper and lower limits of the standard ranges (300–500 ms) for this component [24,48]. Accordingly, in our view, our anterior negativity is a LAN appearing earlier, but not identifiable as an ELAN.

The difference between the SVO and OVS versions at this point in the semantic condition mainly refers to an animate–inanimate dissociation (respectively), and this might be the main variable influencing these results. However, the animacy dimension would not here be independent of the word-order variable, even after considering that filler sentences in the semantic condition included examples of the fact that inanimate nouns can function as subjects. In any sentence, there is always one argument that is most agent-like, the agent often being animate and capable of active events [12] and, in line with the 'Agent First' principle, the first noun in a sentence is usually the agent of that sentence [32].

In a previous study in which the animacy of the nouns used as subjects was manipulated, Weckerly and Kutas [58] found an N400 in the main clause nouns when they were inanimate. Strikingly, the position at which these nouns appeared in the Weckerly and Kutas experiment is closely similar to the one for our nouns that yields an anterior negativity effect instead. That is, they were the second words in the sentences, preceded only by the determiner. At this position, the reader expects to find the noun constituting the subject of the sentence. Accordingly, Weckerly and Kutas interpreted their finding by considering that, since animate subjects are more plausible pragmatically, the violation of the semantic expectancies elicited an N400 effect.

As we see it, our negativity to the first noun in the OVS version in the semantic condition could be reflecting a situation of uncertainty about the subject of the sentence. Since inanimate nouns are less likely to be used as subjects, the appearance of one of these nouns at this position would generate uncertainty over the hypothesis that this is the subject of the sentence. This uncertainty would presumably not occur in our syntactic condition, since parsing could be performed unambiguously according to the preferred SVO order until the moment at which the second determiner appears indicating the reversal of the structure (and, indeed, this would not be a disambiguating point in the strict sense). This could be why we were unable to find an anterior negativity in the syntactic condition. This interpretation may be compatible with the proposal that the anterior negativities are reflecting working memory load [34,58]. A situation of uncertainty would plausibly increase working memory demands if the parser were activating more than one syntactic structure simultaneously.

At the point at which word order is definitely reversed in both conditions, that is, the verb in the semantic condition and the second determiner in the syntactic condition, an apparently comparable result was found. This was the appearance of a late posterior positivity which, accordingly, could be identified with the P600/SPS. Although the distribution of this positivity was fairly dissimilar when comparing the two conditions, statistical analyses did not endorse this difference. And although the use of different samples of subjects when comparing conditions may indeed have decreased the power of the statistical analyses, it is nevertheless true that, overall, both are posterior, mainly parietal, positivities. Results also indicated that the topography of this positivity did not vary significantly across time in either condition. Accordingly, in the present study, a P600/SPS was obtained regardless of the type of cue used to disambiguate word order, and therefore common processes can be assumed when either semantic or syntactic information indicate a reversed word order.

In fact, the main difference between conditions in the P600/SPS relates to the latency and duration of these effects. In the semantic condition, the P600/SPS was of longer duration and peaked later, in comparison to the syntactic condition. A review of the literature indicates that the P600/SPS can notably vary in both latency and duration across studies (e.g., [27,31]), so that both of our posterior positivities are suitably comparable to previously-reported P600/SPS. Indeed, the finding that the P600/SPS varies systematically in amplitude, latency, duration, and even in distribution across a number of studies has been taken as an indication that different aspects of integration subprocesses find their different signatures under the same designation [15]. In this regard, at least two contrasting proposals have been made with respect to the functional role of the P600/SPS. Several researchers suggest that the processes manifested by this late positivity are indicators of a greater syntactic processing cost due to necessary revision and reanalysis of a structural mismatch, which may consist of either an outright syntactic violation [14,47] or a disambiguation of an ambiguous string [19,41,47]. The second perspective views the P600/SPS as related not only to processes of structural reanalysis, but also to processes of repair [26,41]. Even a distributional difference between the P600/SPS evoked by ambiguity resolution (reanalysis-related P600/SPS) and the P600/SPS elicited by syntactic violation (repair-related P600/SPS) has been proposed. While the former has a more central distribution [19], the latter would be characterized by a more posterior parietal distribution [11,26,57].

In the present study, both posterior positivities in either condition displayed a clearly posterior distribution, with the possible exception of the P600/SPS for the 500–600 ms window in the syntactic condition, which, nevertheless, did not significantly differ in statistical terms when compared to the other, clearly posterior topographies. Thus, the above-mentioned proposed distributions for the different subprocesses reflected by the P600/SPS would not stand in the light of our results, since no repair-related processes due to a syntactic violation could be accounted for in our material. Indeed, several studies have also reported parietal distributions of the P600/SPS accompanying ambiguity resolutions (e.g., [39]).

Regardless of this topography debate, the fact that we could not find a remarkably different topography when comparing the P600/SPS between conditions indicates that similar processes are occurring after the disambiguation point in either condition. The differences in latency and duration of the P600/SPS when comparing conditions are most probably attributable, in our opinion, to differences in the distance between the disambiguating point and the last word in the sentence. This distance is longer (one word more; 500 ms including the interstimulus interval) in the semantic condition. In this condition, moreover, the word in between (the second determiner) is in fact irrelevant for determining word order. Accordingly, our positivities are most probably reflecting the costs of additional processing necessary for the computation of a new syntactic structure when a previously-built structure, constructed on the basis of preferences in word order (essentially, on the basis of the 'Agent First' principle) has been found to be inadmissible. In this sense, what occurs when word order is varied would not notably differ from what is occurring when other syntactic anomalies are taking place. Importantly, our results indicate that this is occurring regardless of the type of information (either semantic or syntactic) triggering a variation of word order.

It should be mentioned here that the finding of a P600/SPS in the semantic condition may indicate that the presence of an inanimate noun in the first NP is not sufficient for ruling out the processor's preference for assigning the first NP as the subject of the sentence. Indeed, an inanimate noun can be the subject of a sentence (a wall can be red, fall, prevent entering, etc.), and our fillers included examples of this kind. Thus, even if the anterior negativity found for the first noun when it was inanimate may reflect that more than one syntactic structure is activated simultaneously, one of these structures (based on word order) is preferred, and is the main one used to integrate incoming words. This could be compatible with Gibson's [20] proposal that the set of representations considered by the processor is divided into two sets: one (the active representation set) in which the representations are being considered as integration sites for incoming words; and a second (the inactive representation set) in which the representations are no longer being considered as integration sites for incoming words. Although the inactive representations are not worked on, they remain in the representation space with low activation, so that they may be reactivated later in a reanalysis stage if an incoming word cannot be integrated with the representations in the active representation set [20].

We were unable to find the early parietal positivity (P345) reported by several authors [7,17,41] and presumably reflecting thematic reanalysis. In those studies, however, the information affecting word order and eliciting the P345 occupied the very last position in the clause or sentence, whereas in the present study it occupied an intermediate position. This important difference might explain these different results, but further research is certainly needed in order to overcome the scarcity of studies on word-order variation cued by semantic information.

Two more features deserve some comments. One is that we found a posterior negativity for the final word (the second noun) in the OVS sentences in the semantic condition. Although its duration was rather long, the fact that it yielded post hoc significant results or a trend for significance only in the 300–500 and the 500–800 ms windows and in the right parieto-medial regions could relate this fluctuation to N400-like processes. Rösler et al. [52] reported an N400 at the very end of non-canonical sentences. According to these authors, the system may automatically interpret the final noun as the direct object; if inanimate nouns are usually expected as direct objects, there would be a semantic mismatch when an animate noun appears in this position. This, in turn, might explain why this negativity failed to appear in the syntactic condition when comparing SVO and OVS sentences, as in this condition the final noun was always animate. As an alternative explanation, this negativity might in fact be a consequence of the baseline correction used to analyze that word. Indeed, the baseline could be affected by the differences starting earlier in the critical verb region, which caused effects of opposite polarity and in similar regions. Even so, it is true that this negativity displayed a slightly right distribution (supported by statistical analyses), contrasting with the clearly bilateral distribution of the posterior positivity occurring shortly after the disambiguation point in this condition.

Another relevant point is that a frontal positivity appeared at the very end of the sentence in both conditions for OVS sentences. Although post hoc analyses did not yield significant results, overall ANOVAs did so in both conditions, so that this positivity might have some entity. This fluctuation appeared very late in the longer epochs, presumably far ahead of the time at which the complete sentence had been processed. Accordingly, it may relate to subsequent processes, those related to participants' report about the subject of the sentence. The main difference between SVO and OVS sentences at this point is that whereas the report in the latter case relates to a noun that has just appeared, it relates in the SVO sentences to a noun appearing 1500 ms earlier and followed by other words. Although this is somewhat speculative, it is possible that differential operations within working memory are at the basis of these fluctuations appearing at the very end of the sentence.

That the disambiguating cues in the semantic and syntactic conditions differed in the position within the sentence, and therefore in the word type, is a caveat of this study. Indeed, these dissimilarities may account for several of the differences in the results found here, as already discussed. This is particularly the case for differences in the time course of the posterior positivities. Even so, the finding of a late posterior positivity when semantic information determines syntactic structural properties of the sentence is a relevant finding in itself. This would be true even if no syntactic condition equating in several other variables were used for comparison purposes.

In conclusion, this study contributes to the claim that word order is used by the parser as a syntactic rule, which can be "violated", and hence yield ERP fluctuations usually obtained with syntactic manipulations (namely, LAN and P600/SPS). This would be the case regardless of the type of information (either syntactic or semantic) determining word order in a given sentence.

Acknowledgments

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Appendix A. Examples of the experimental sentences are listed with word-for-word English translations and non-literal interpretation.

A.1. Semantic condition

1a. *El tenor$_{[Subject]}$ cantó$_{[Verb]}$ la ópera$_{[Direct\ Object]}$*.The tenor$_{[Subject]}$ sang$_{[Verb]}$ the opera$_{[Direct\ Object]}$ (=The tenor sang the opera.)

1b. La ópera$_{[Direct\ Object]}$ cantó$_{[Verb]}$ el tenor$_{[Subject]}$.The opera$_{[Direct\ Object]}$ sang$_{[Verb]}$ the tenor$_{[Subject]}$. (=The opera was sung by the tenor.)

2a. *El capitán$_{[Subject]}$ denegó$_{[Verb]}$ el permiso$_{[Direct\ Object]}$*. The captain$_{[Subject]}$ denied$_{[Verb]}$ the permission$_{[Direct\ Object]}$ (=The captain denied the permission.)

2b. El permiso$_{[Direct\ Object]}$ denegó$_{[Verb]}$ el capitán$_{[Subject]}$. The permission$_{[Direct\ Object]}$ denied$_{[Verb]}$ the captain$_{[Subject]}$. (=The permission was denied by the captain.)

3a. *El cartero$_{[Subject]}$ cerró$_{[Verb]}$ el buzón$_{[Direct\ Object]}$*. The postman$_{[Subject]}$ closed$_{[Verb]}$ the mailbox$_{[Direct\ Object]}$ (=The postman closed the mailbox.)

3b. El buzón$_{[Direct\ Object]}$ cerró$_{[Verb]}$ el cartero$_{[Subject]}$. The mailbox$_{[Direct\ Object]}$ closed$_{[Verb]}$ the postman$_{[Subject]}$. (=The mailbox was closed by the postman.)

4a. *El gato$_{[Subject]}$ rasgó$_{[Verb]}$ la cortina$_{[Direct\ Object]}$*. The cat$_{[Subject]}$ tore$_{[Verb]}$ the curtain $_{[Direct\ Object]}$ (=The cat tore the curtain.)

4b. La cortina$_{[Direct\ Object]}$ rasgó$_{[Verb]}$ el gato$_{[Subject]}$. The curtain$_{[Direct\ Object]}$ tore$_{[Verb]}$ the cat$_{[Subject]}$. (=The curtain was torn by the cat.)

5a. *La actriz$_{[Subject]}$ eligió$_{[Verb]}$ el restaurante$_{[Direct\ Object]}$*. The actress$_{[Subject]}$ chose$_{[Verb]}$ the restaurant$_{[Direct\ Object]}$ (=The actress chose the restaurant.)

5b. El restaurante$_{[Direct\ Object]}$ eligió$_{[Verb]}$ la actriz$_{[Subject]}$. The restaurant$_{[Direct\ Object]}$ chose$_{[Verb]}$the actress$_{[Subject]}$. (=The restaurant was chosen by the actress.)

A.2. Syntactic condition

1a. *El luchador$_{[Subject]}$ hirió$_{[Verb]}$ al árbitro$_{[Direct\ Object]}$*. The wrestler$_{[Subject]}$ hurt$_{[Verb]}$ the referee$_{[Direct\ Object]}$ (=The wrestler hurt the referee.)

1b. El luchador$_{[Direct\ Object]}$ hirió$_{[Verb]}$ el árbitro$_{[Subject]}$. The wrestler $_{[Direct\ Object]}$ hurt$_{[Verb]}$ the referee$_{[Subject]}$. (=The wrestler was hurt by the referee.)

2a. *El socio$_{[Subject]}$ despidió$_{[Verb]}$ al comercial$_{[Direct\ Object]}$*. The partner$_{[Subject]}$ fired$_{[Verb]}$ the salesman$_{[Direct\ Object]}$ (=The partner fired the salesman.)

2b. El socio $_{[Direct\ Object]}$ despidió$_{[Verb]}$ el comercial$_{[Subject]}$. The partner$_{[Direct\ Object]}$ fired$_{[Verb]}$ the salesman$_{[Subject]}$. (=The partner was fired by the salesman.)

3a. El rey$_{[Subject]}$ condecoró$_{[Verb]}$ al comandante$_{[Direct\ Object]}$. The king$_{[Subject]}$ decorated$_{[Verb]}$ the commander$_{[Direct\ Object]}$ (=The king decorated the commander.)

3b. El rey$_{[Direct\ Object]}$ condecoró$_{[Verb]}$ el comandante$_{[Subject]}$. The king$_{[Direct\ Object]}$ decorated$_{[Verb]}$ the commander$_{[Subject]}$. (=The king was decorated by the commander.)

4a. *El gobernador$_{[Subject]}$ acompañó$_{[Verb]}$ al general$_{[Direct\ Object]}$*.The governor$_{[Subject]}$ accompanied$_{[Verb]}$ the general$_{[Direct\ Object]}$ (=The governor accompanied the general.)

4b. El gobernador$_{[Direct\ Object]}$ acompañó $_{[Verb]}$ el general $_{[Subject]}$. The governor$_{[Direct\ Object]}$ accompanied$_{[Verb]}$ the general$_{[Subject]}$. (=The governor was accompanied by the general.)

5a. *El sargento$_{[Subject]}$ arrestó$_{[Verb]}$ al guardia$_{[Direct\ Object]}$*. The sergeant$_{[Subject]}$ arrested$_{[Verb]}$ the guard$_{[Direct\ Object]}$ (=The sergeant arrested the guard.)

5b. El sargento$_{[Direct\ Object]}$ arrestó$_{[Verb]}$ el guardia$_{[Subject]}$. The sergeant$_{[Direct\ Object]}$ arrested$_{[Verb]}$ the guard$_{[Subject]}$. (=The sergeant was arrested by the guard.)

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