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Electrophysiological evidence of an early effect of sentence context in reading

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Abstract

Recognition Potential is an electrophysiological response of the brain that is sensitive to semantic aspects of stimuli. According to its peak values (about 250 ms), Recognition Potential appears as a good candidate to reflect lexical selection processes. Consequently, Recognition Potential might be sensitive to contextual information during reading a sentence. In present study, the standard procedures to improve the visibility of Recognition Potential (Rapid Stream Stimulation paradigm) were used in a task in which sentence context was crucial. A parieto-occipital Recognition Potential was observed to peak about 264 ms after stimulus onset, followed by a centro-parietal N400 peaking at about 450 ms. Recognition Potential was affected by contextual information though, contrary to N400, presenting larger amplitude to contextually congruous words. These results support the assumption that Recognition Potential may reflect lexical selection processes, representing also evidence of context effects on ERP around 250 ms after stimulus onset during sentence reading.

Keywords: Recognition potential; N400; Lexical access; Lexical integration

1. Introduction

Recognition Potential (RP) is an electrical response of the brain that displays an inferior parieto-occipital distribution and occurs when a subject views recognizable images of

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words (Rudell, 1991; Rudell and Hua, 1997; Martín-Loeches et al., 1999). RP is strongly related to conscious awareness of stimuli, selective attention being an important factor for evoking RP (Rudell and Hua, 1996a). Moreover, although it has mainly been studied as a language-related ERP component, RP can also be elicited by pictures (Rudell, 1992; Hinojosa et al., 2000).

It has been recently established that RP would be actually reflecting, at least to some extent, the semantic processing of images, disregarding the possibility that RP merely reflects the reaction to lower levels of word image analysis such as orthographic or letter identification, rather than semantic or conceptual analyses (Martín-Loeches et al., 2001a). Hence, RP amplitude has been shown to consistently differ in accordance with word features that can only be achieved by means of an appropriate semantic processing. In this regard, RP amplitude differs as a function of the semantic category of the stimuli (Martín-Loeches et al., 2001a), being also larger for concrete than for abstract words (Martín-Loeches et al., 2001b) or for open as compared to closed-class words (Hinojosa et al., 2001a). These phenomena could never be attributed to factors other than semantic content, such as stimulus familiarity, which have been seen to affect RP latency, but not its amplitude (Rudell and Hua, 1997) and have been always appropriately controlled.

Conversely, RP reaches its peak at about 250 ms (Rudell, 1992), though several experimental manipulations may increase or decrease this latency (Rudell, 1991; Rudell and Hua, 1995, 1996b, 1997). Thus, the importance of RP appears as certainly outstanding, especially considering that the other ERP component systematically related to semantic information processing during reading has been the N400 (Kutas and Hillyard, 1980, 1984; Kutas et al., 2000), which may peak hundreds of milliseconds later. The N400 is a centrally distributed negativity that presents its peak amplitude at about 400 ms after stimulus onset, appears when a semantic incongruence takes place, and can be elicited by either words or pictures (Kutas, 1997).

In traditional models of psycholinguistics, the words are represented in a *lexicon*, the reader's or hearer's mental representation of word forms and word meanings. Successful word reading or hearing occurs when input from a string of letters or of phonemes, activating one or more word forms in the lexicon, results in the word corresponding to the input string—rather than some other word—being identified. In this regard, most models from the psycholinguistics propose that word recognition might engage at least three different subprocesses. Firstly, the initial input activates a set of compatible entries during *lexical access*, a pre-semantic first stage. This is a purely form-based process and is classically considered as independent of the lexical information relative to the meaning of the perceived word. The second stage, called *lexical selection*, would already convey to a large extent single-word meaning processing. Along this stage, the best of these candidates is chosen as the preferred one. This is an intermediate process in which form-based and content-based information are combined to select the appropriate word. That is, a lexical item or entry composed by a word form and a word meaning is selected. Thirdly, during post-lexical processing, the entry that has been selected is integrated into a higher order representation of the context provided by the enunciates, namely the integration of word meaning into sentence context or *lexical integration*. This third stage is purely content-based. Although these stages have been mainly proposed in the field of auditory processing (Zwitserlood, 1989; Cutler and Clifton, 1999; Marslen-Wilson, 1989), their applicability to the reading processes could suitably be assumed, as is specially the case for the second and third stages.

When dealing with reading processes, the specific feature usually pointed out is the possible existence of two distinct pathways to the identification of the words. In this regard, a widely accepted model is the Dual Route Theory (Coltheart et al., 1977; Paap and Noel, 1991). According to this model, two routes are proposed: one provides direct contact to a word representation from the graphic input (‘addressed’ route), whereas the second route converts graphemes into phonemes, which are used to access the word representations (‘assembled’ route). Whichever the route employed, the final stage in word reading is semantic activation. Therefore, reading a word would entail graphic and/or phonological activations necessarily ending in a semantic activation (Perfetti, 1999), and then occurring lexical selection.

Based on several behavioral measurements, including eyes fixation data, it can be asserted that the graphic, phonological, and meaning information sources that come together in the identification of a printed word become available over a brief time period, at about 250 ms (Rubin and Turano, 1992; Sereno et al., 1998). Hence, considering its peak latency (about 250 ms) and the facts that RP has always been reported in single-word experiments and is modulated by the semantic content of the words, it appears highly plausible that this component would be a good candidate to reflect lexical selection processes, a stage in which, as already commented, content-based information becomes essential.

Thereafter, the mechanism underlying the N400 would more likely reflect a relatively late post-semantic process, as has been already proposed (Holcomb, 1993; Chwilla et al., 1995; though see Deacon et al., 2000), presumably lexical integration (Hagoort and Brown, 2000; Van den Brink et al., 2001). The fact that N400 is essentially sensitive and more typically obtained to semantic violations of sentence context (Kutas and Hillyard, 1984; Kutas et al., 1999) would reinforce this argument. At this regard, when N400 has been reported to isolated words, these have been the second members of word pairs (Bentin et al., 1985; Holcomb and Neville, 1990). This would, at least to some extent, engender some kind of context into which the second member of the pair might be integrated. Actually, N400 appears as a function of the semantic incongruity between the second and the first members of each pair. RP, by contrast, has been often obtained for strictly isolated words. Accordingly, N400 seems to reflect lexical integration whereas RP might reflect lexical selection.

Lexical selection is nevertheless a context-sensitive stage. Reading a sentence is a complex process in which both bottom-up and top-down processes would continuously interact. In this regard, the selection of the best candidate during lexical selection is aided by contextual information when the word is embedded into a sentence (Jackendoff, 1999; Perfetti, 1999).

However, context effects at the time lexical selection is taking place have been reported during spoken sentence processing, but they have not been conventionally observed to written processing, despite the presumed commonality of lexical selection processes to both spoken and written languages (Hagoort and Brown, 2000; Van den Brink et al., 2001). Connolly et al. (1995) reported a possible early effect of context during reading—a left frontotemporal negativity in the 250–300 range—but this appeared *only* if there was also a phonological violation; therefore complicating its definite assignment as reflecting lexical selection processes. Hagoort and Brown (2000) argue that this state of affairs might be due to at least two reasons. First, during visual presentation word information is immediately fully available, the separation in time between lexical selection and lexical integration being substantially smaller than in spoken language, earlier effects being hardly separable from N400 effects due to overlapping phenomena. Second, studies on reading use short words to avoid eye movements, which would again convey a hard separation of both semantic processes.

Both reasons might be discarded if RP were modulated by contextual information. However, the procurement of RP in previous sentence reading experiments has probably been prevented by the confluence of several circumstances. First, RP can be observed in normal sentence reading, particularly at certain SOAs (Iglesias et al., in press), but its appearance is mainly manifest in a scarcely employed electrode, PO7 (left parieto-occipital). It can also be observed at occipital leads, but researchers' attention has not usually been summoned on these electrodes during psycholinguistic experiments. Also, its plain amplitude is better seen when using a special procedure, called Rapid Stream Stimulation (RSS), that is somewhat similar to the Rapid Serial Visual Presentation (RSVP) paradigm used in psycholinguistic experiments, but where both words and non-words (rather, non-sense masks or *background* stimuli) alternate. The aim of the RSS is to permit the recording of ERP activity to rapidly presented real words without recording overlapping linguistic processes related to preceding word stimuli, therefore improving the visibility of RP (Hinojosa et al., 2001b; Iglesias et al., in press). In Iglesias et al. (in press) it can be seen that RP appears in more natural sentence presentations (i.e. without background stimuli) but with a significantly decreased amplitude. Finally, RP amplitude is also enhanced by the use of a global average reference (Martín-Loeches et al., 2001), a scarcely employed procedure in the ERP literature on language processing. A combination of at least some of these features may be on the base of the absence of an RP reported in studies dealing with context effects during reading.

Accordingly, the aim of present study is to investigate the effects of contextual information on RP. In the present study, we combine the standard procedures for obtaining RP with the standard procedures for obtaining N400, by presenting word stimuli using a RSS paradigm in a task in which sentence context is crucial.

Hence, the stimulation paradigm involved very brief (250 ms) visual presentations of real words preceded and followed by the consecutive and also brief visual presentation of several background stimuli. Consecutive sequentially appearing real words made up five-word meaningful sentences containing a transitive verb. The terminal word in each sentence, which was also followed by a sequence of background stimuli, could be semantically congruous or incongruous with the rest of the sentence. From the total of sentences presented to each subject, 50% had a congruous and 50% an incongruous sentence-ending word. Exactly the same words used as semantically congruous for half of the subjects were incongruous for the other half, and vice versa. We recorded the brain electrical activity related to these sentence-ending words, for which both single-word meaning and sentence context analyses were required, since subjects were occasionally asked about the content of the sentences. With this procedure we expected to obtain both RP and N400. This procedure resembles the employed for enhancing RP, therefore this potential should be clearly apparent. Also, the existence of semantic context violations should force the appearing of N400 phenomena, which would be used as controls for context effects in present study.

2. Methods

2.1. Subjects

Thirty native Spanish-speaking students (17 females, mean age 23 years, range 20–27) were paid for their participation in the experiment. They were right handed, with average handedness scores of +84, ranging from +47 to +100 according to the Edinburgh Handedness Inventory (Oldfield, 1971). All participants had normal or corrected-to-normal vision.

2.2. Stimuli

Words were presented embedded in a stream of background (non-sense masks) stimuli as will be detailed in the procedure section. Sequentially appearing words made up meaningful sentences. A total of 60 congruous experimental sentences were initially constructed. All sentences were transitive constructions, each containing five words. The definition of a sentence as congruous was based on the unanimous judgment by five external reviewers. Also, as final words were crucial, cloze probability was calculated based on judgments by a group of 30 subjects others than the experimental subjects of the present study. The mean cloze probability for final words was 52%.

The structure of these sentences was as follows: determinant-subject-verb-determinant-object. Nouns and verbs were two- or three-syllable frequent words. All verbs were regular and they were conjugated in past tense. From each of these 60 sentences a further version was constructed in which final words were semantically incongruous with previous sentence contexts. These errors were realized by randomly interchanging final words of the congruous sentences with the constraint that word-endings were not congruous with the semantic context of the resulting new sentence, according to the unanimous judgment by the same five external reviewers who examined congruous versions. Also, cloze probability for final words was calculated for these incongruous versions, yielding a 0% value. By this procedure, the same words were used either as semantically congruous or as incongruous. An example of each sentence type is given bellow (with literal English translation):

(1) Congruous word-ending:
El jugador metió un *tanto*
The player scored a *goal*.
(2) Incongruous word-ending:
El jugador metió un *sueldo*
The player scored a *wage*.

Sentences were presented in lower case letters with the exception of the first letter of the first word that was an upper case letter. Two sets of 60 sentences, each containing 30 congruous and 30 incongruous sentence-ending words, were constructed. In order to avoid sentence repetition, each set was presented to 15 subjects.

Background stimuli were made by cutting sentence-ending nouns in '*n*' portions (*n*: number of letters that compose a word minus one). These portions were repositioned according to certain rules: the last piece of the word was placed in the first position of the new stimulus, and vice versa; the penultimate portion was placed in the second position, and vice versa; and so on. Another set of background stimuli were made by replacing portions randomly. Therefore, there were 120 background stimuli. Each stimulus made by these methods had at least two complete letters, but also clearly identifiable non-letters (formed by the fusion of different letter fragments). Although this method to construct background stimuli is not the most standard in psycholinguistics, where usually consonant strings are employed, it was preferred as this type of stimuli are actually the standard controls in RP research: they resemble words in many perceptual features (luminance, size, etc.) but are devoid of certain linguistic variables (Martín-Loeches et al., 1999). Even though, either use of non-words formed by consonant strings or those used here would presumably not yield substantial differences (Martín-Loeches et al., 1999, 2001a).

All stimuli were matched in visual aspects. They were presented white-on-black on a NEC computer MultiSync monitor, controlled by the Gentask module of the STIM package (NeuroScan Inc.). Subjects eyes were 65 cm from the screen. All stimuli were between 0.7 and 1.3° high, and between 1.1 and 5.9° wide.

2.3. Procedure

Participants were tested in a single experimental session and were presented with the 60 sentences. They were instructed to read the experimental sentences for comprehension and to answer questions when required. A practice block was allowed to participants before the experimental session began. None of the sentences used in the training were experimental sentences. At the beginning of the experimental session subjects had to push a button and a message appeared in the screen telling them they could blink as much as they wanted in order to avoid blinking during stimulus presentation, and to push again to start the session. Stimuli were presented according to the Rapid Stream Stimulation paradigm (Martín-Loeches et al., 1999; Rudell, 1992) with a stimulus onset asynchrony (SOA) of 250 ms.

After six or seven background stimuli (this number randomized) the first word of the sentence appeared. The rest of the words appeared consecutively after a variable number of background stimuli (2–4, this number randomized in order to avoid anticipatory processes, see Rudell, 1992) until the sentence was completed. The last word of every sentence was followed by a period in order to notice the end of the sentence to subjects. Six or seven background stimuli (this number randomized) were presented between the last word of a sentence and the first word of the new sentence. An example of this procedure for the sentence *El jugador metió un tanto* (*The player scored a goal*), where *nw* refers to non-word, would be: *nw-nw-nw-nw-nw-nw-El-nw-nw-nw-nw-jugador-nw-nw-metió-nw-nw-nw-un-nw-nw-tanto.-nw-nw-nw-nw-nw-nw*. Fig. 1 also exemplifies the stimulation procedure, displaying a sentence's sample and the appearance of both the words and the non-words.

Every 4–6 sentences (this number randomized) subjects were presented with a comprehension probe question about the contents of the immediately preceding experimental sentence. Questions appeared in full on the screen. Half of the questions had an affirmative response whereas the remainders had a negative response. Participants gave yes–no answers to the questions and were allowed to blink. After doing so, they had to press a button in order to keep with sentence presentation.

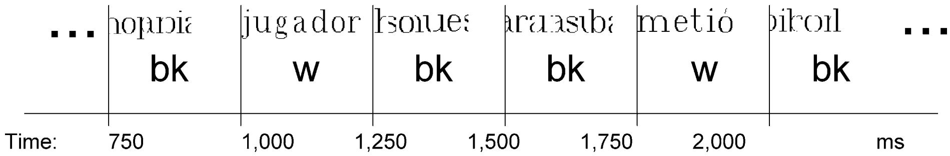

Fig. 1. Sample of the stimulation procedure. 'W' refers to words, whereas 'bk' refers to background stimuli. Words appeared consecutively after a variable number of background stimuli (2–4, this number randomized) until a sentence was completed.

2.4. Electrophysiological recordings

Scalp voltages were recorded from 59 tin electrodes that were embedded in an electrode cap (electroCap International). Scalp locations were: 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 (American Electroencephalographic Society, 1991), 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 recorded from bellow versus above the left eye (vertical EOG) and the left versus right lateral orbital rim (horizontal EOG). Electrode impedances were kept below 3 kΩ. The signals were recorded continuously with a bandpass from direct current (DC) to 100 Hz and a digitization sampling rate of 250 Hz. The data were filtered off-line using a 0.01–50 Hz bandpass.

2.5. Data analysis

EEG epochs were extracted starting 200 ms before and lasting 1024 ms after the presentation of each stimulus. Artifacts were automatically rejected by eliminating those epochs that exceeded $\pm 65\,\mu V$ and those with amplifier saturation artifacts. Additionally, a visual inspection was performed. Approximately 11% of the trials were excluded for these reasons. Offline correction of smaller eye movement artifacts was also made, using the method described by Semlitsch et al. (1986). For the entire sample of electrodes, originally M2-referenced data were re-referenced off-line using the average of the mastoids (M1 and M2) method. ERP averages were aligned to a -200 ms prestimulus baseline and computed separately for congruous and incongruous words, as much as for 30 randomly selected background stimuli.

Repeated-measures analyses of variance (ANOVAs) were performed with the purpose of amplitude comparisons between congruous final words and incongruous final words. Amplitude was measured as the mean amplitude of a particular time interval. To avoid a loss of statistical power when repeated-measures ANOVAs are used to quantify large number of electrodes (Oken and Chiappa, 1986) analyses on amplitude were conducted on a selected sample of 38 electrodes: Fp1, Fpz, Fp2, AF3, AF4, F5, F1, Fz, F2, F6, FC5, FC1, FCz, FC2, FC6, C5, C1, Cz, C2, C6, CP5, CP1, CPz, CP2, CP6, P5, P1, Pz, P2, P6, PO7, PO1, POz, PO2, PO8, O1, Oz, and O2. These ANOVAs included two factors: type of stimulus (2 levels: congruous word, incongruous word) and electrode (38 levels). The Geisser–Greenhouse correction for non-sphericity was always applied. Finally, in order to prevent type I error (e.g. Sankoh et al., 1997; Perneger, 1998), and for the sake of simplicity, post hoc Bonferroni comparisons on amplitude were performed only in the electrode showing the highest amplitude for each particular ERP component.[1] Statistics were always performed on original non-subtracted data.

3. Results

Behavioral data revealed a mean of 95.8% of correct responses (range 75–100%) to the comprehension probe questions (see Section 2), which undoubtedly indicates that subjects were correctly performing the sentence comprehension task, as requested.

Sentence-ending words elicited a distinctive waveform characterized by several components (Fig. 2). Fig. 3 represents same data as Fig. 2, but responses for background stimuli have been subtracted from each of the waveforms to visually enhance target components by removing driving rhythm activity. However, statistical analyses will be always performed on raw, non-subtracted data. At the left parieto-occipital electrodes RP can be clearly recognized. It peaked about 264 ms after stimulus onset for both congruous and incongruous stimuli. The amplitude of this component was maximal at PO7 electrode, and larger for semantically congruous words than for incongruous words. A repeated-measures ANOVA was performed on the 226–292 ms time window (peak ±28 ms, a standard procedure to define RP time window; see Martín-Loeches et al., 2001b), and revealed significant type of stimulus by electrode interaction ($F_{37,1073} = 25.2$; $P < 0.0001$; $\varepsilon = 0.007$). Post hoc comparisons at PO7 confirmed the significant difference between congruous and incongruous words ($F_{1,29} = 5.4$; $P = 0.027$) along this time window.

At the centro-parietal electrodes N400 can be clearly recognized. It peaked about 450 ms after stimulus onset and was maximal at CPz. An ANOVA was also applied, now on the 350–550 ms time window, revealing significant type of stimulus by electrode interaction ($F_{37,1073} = 2.7$; $P < 0.05$; $\varepsilon = 0.103$). Post hoc comparison at CPz confirmed the significant difference between congruous and incongruous words ($F_{1,29} = 8.3$; $P = 0.008$) along this time window.

Fig. 4 represents the topographic distributions of both RP and N400 after subtracting responses to background stimuli. All data are represented and analyzed using the average mastoids reference, although RP would display its best values using the common average-reference method (Martín-Loeches et al., 2001a). This implies that RP amplitude is here similar or even smaller than distant positive fluctuations. However, the common average-reference method is not a customary procedure to obtain N400. Fig. 4a displays the topo-

[1] It has to be considered that much of what is recorded in the other electrodes is a product of volume conduction. Therefore, including more electrodes in post hoc comparisons would be redundant while increasing type I error. This is the procedure used in all our previous RP research, and is also widely used by several other authors (e.g. Pfütze et al., 2002).

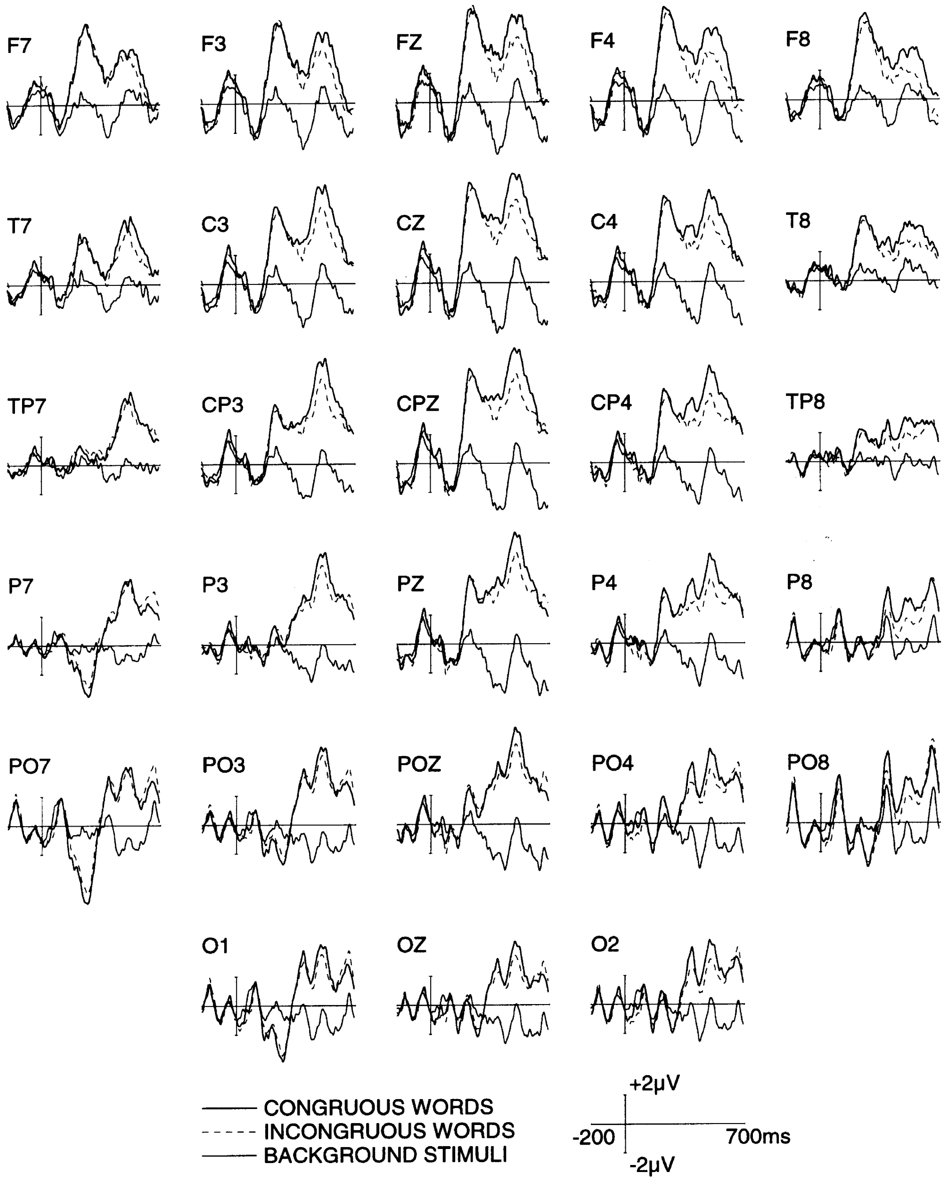

Fig. 2. Grand-averaged ERP at a selected sample of electrodes. The selection is made to improve visibility of main effects while avoiding redundancy. A clear Recognition Potential (RP) can be identified for both congruous and incongruous words. Also, the comparison between congruous and incongruous words yields a clear N400 component.

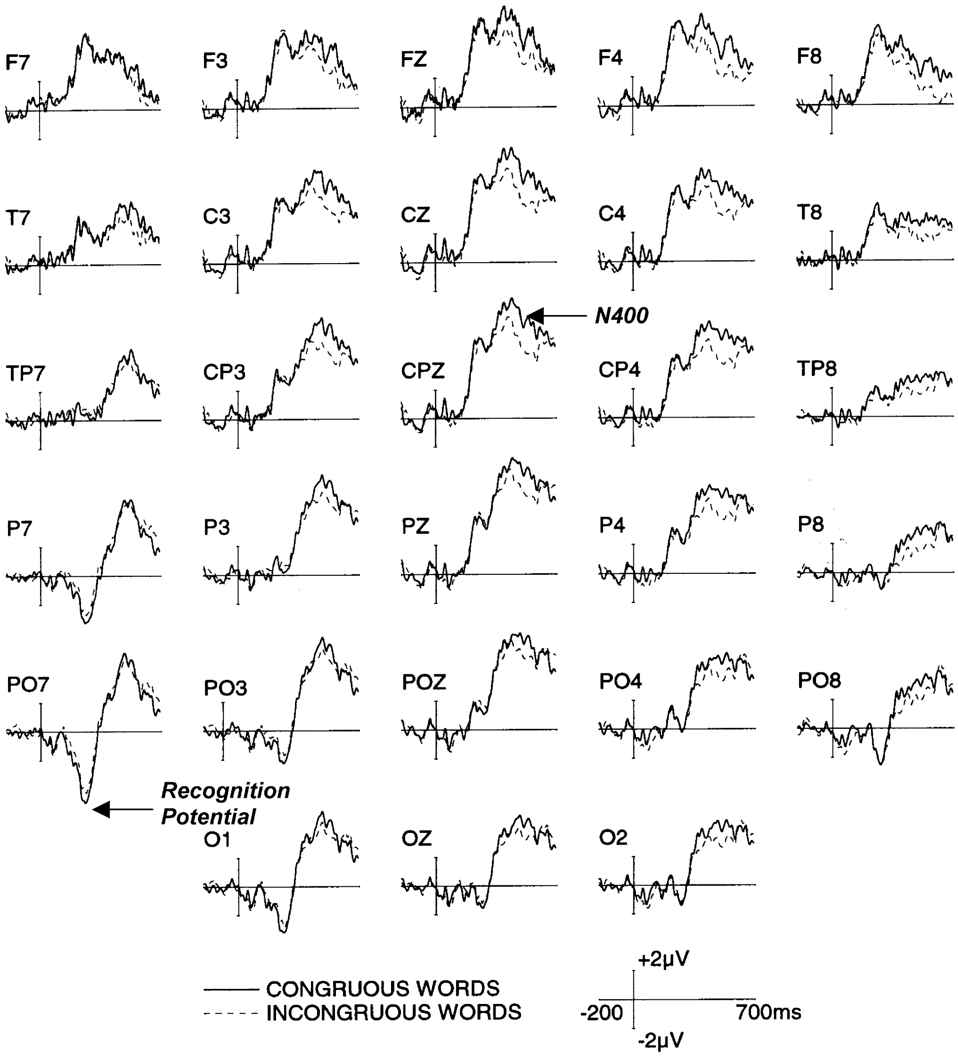

Fig. 3. Same data as Fig. 2, after subtracting responses to background stimuli from each of the waveforms for semantically congruous and incongruous words in order to visually enhance the RP and the N400 components.

graphic pattern of RP after subtracting congruous from incongruous stimuli, that is, the RP enhancement as a consequence of context effects. However, as congruous stimuli yielded higher RP values, this subtraction (performed to make this map comparable to that in Fig. 4b) entails a positive-like activity of this actually negative component. The topography of this component reveals its typical left-lateralized inferior parieto-occipital distribution, which is not limited to PO7 but extends to neighbor positions. Fig. 4b displays the topographic pattern of N400. This component is typically obtained by subtracting congruous from in-

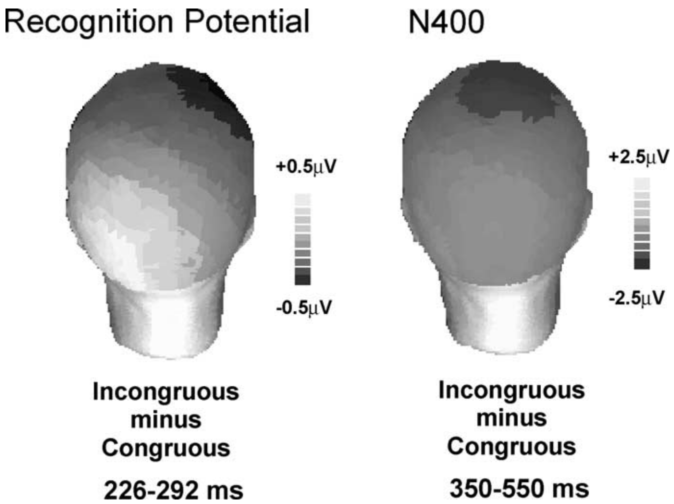

Fig. 4. Topography of the components related to semantic processing across the total array of 58 cephalic electrodes after subtracting the activity for background stimuli. The maps represent mean values for the time periods outlined below each map. (a) Recognition Potential, with a left parieto-occipital distribution. The counterpart activity over right frontal regions appears of relatively similar magnitude as compared to RP effects due to the use of mastoids reference (b) N400, with a centro-parietal distribution. Both, RP and N400, are represented as the difference between incongruous and congruous words, which is the customary procedure to achieve N400.

congruous stimuli (Kutas et al., 2000), and this is represented in Fig. 4b. N400 displays its typical slightly right centro-parietal distribution. A profile analysis (McCarthy and Wood, 1985) substantiating the different topography for RP and N400 was considered redundant and not performed, given the remarkable differences observed between both components—a left parieto-occipital negativity for RP and a slightly right centro-parietal negativity for N400.

4. Discussion

The main finding of present study is the modulation of RP by sentence context information. Several authors have proposed that lexical access is insensitive to context information whereas lexical selection is affected by such information (Jackendoff, 1999; Perfetti, 1999). Hence, this result would support the assumption that RP may reflect lexical selection processes rather than lexical access. This is a valuable contribution in order to better characterize this ERP component and its implications as a tool in the study of language-processing by the human brain.

Additionally, present results would constitute evidence of context effects on ERP peaking around 250 ms (the peak of RP was actually about 264 ms) during reading. This would convey that the reasons proposed by Hagoort and Brown (2000) for the absence of ERP modulations by contextual information around 250 ms in visual sentence processing would appear no longer maintainable. To remind, these authors suggested that the use of short words and the instantly full availability of word information in visual sentence presentation might account for that circumstance, as lexical selection and lexical integration would become hardly separable. However, in present experiments words were short and immediately fully available, but context effects were found around 250 ms.

Consequently, what we have is that lexical selection might be reflected by a N250 or N200 with a central distribution in spoken language (Hagoort and Brown, 2000; Van den Brink et al., 2001), whereas this stage might be reflected by a parieto-occipital negativity around 250 ms (RP) in written language. If this were the case, this different topography would entail an additional consequence regarding differences between modalities in lexical selection processes. As stated in the Section 1, lexical selection is an intermediate process in which form-based and content-based information are combined to select the appropriate word (Marslen-Wilson, 1989). If this is the case, it appears plausible the different topography for the same process in different modalities. Whereas content-based information might be assumed to be common to either modality, this should not be the case for word-form information (Engelkamp and Rummer, 1999), unless we assume the ‘assembled’ route of the Dual Route Theory as obligatory, which is a matter of open debate (Perfetti, 1999). Our data cannot refute either the validity or the inevitability of the ‘assembled’ route, but would rather support the reality of the ‘addressed’ route.

Our results would further support that both lexical selection and lexical integration would occur at openly discernable brain areas. The fact that RP and N400 display remarkably dissimilar topographies substantiates this argument. Accordingly, whereas RP displayed its standard perieto-occipital maximum, mainly left, N400 showed a parieto-central maximum, slightly right. This distribution of N400, in turn, confirms that a genuine N400 was here obtained (Kutas, 1997), disregarding other analogous components as the left anterior negativity (or LAN), which displays a more left frontal distribution (Münte et al., 1998).

Although a basal temporal origin for both RP and N400 has been proposed, more anterior basal portions of the temporal lobe would generate N400, whereas RP seems to be generated by more posterior or medial basal temporal areas. Information on brain generators for these components has been obtained by means of dipole solutions in the case of RP, whereas both dipole solutions and intracerebral recordings have confirmed the N400 origin here described (Johnson and Hamm, 2000; Martín-Loeches et al., 2001a; Nobre et al., 1994). Interestingly, basal temporal and inferior temporal activation has been consistently reported as accompanying language semantic processing in haemodynamic experiments both during sentence processing and single-word experiments (e.g. Büchel et al., 1998; Chee et al., 1999; Hagoort et al., 1999; Kuperberg et al., 2000; Keller et al., 2001). Likewise, the visual word form area has been proposed to be located within these regions (Dehaene et al., 2002).

Worthy of mention is the question that we are here assuming that RP is indeed reflecting lexical selection. Its latency, its modulation by the semantic content of the words and the here observed modulation by the context of the sentence in which the word is embedded largely support this assumption. A narrowly comparable reasoning was followed by Hagoort and Brown (2000) and Van den Brink et al. (2001) for their N250 and N200, respectively, in the auditory modality. However, the robustness of this assertion would be further validated if future research proved the sensibility of RP to other features that presumably affect lexical selection, as could be the selection of word meanings for ambiguous words (Simpson, 1994).

In this regard, RP might be reflecting only the conceptual encoding constituent of lexical selection, that is, a non-linguistic meaning access after a word's graphic or phonological encoding has taken place. Indeed, some models would admit the possibility of an access to word meaning completely independent and separated from the word-form (e.g. Pulvermüller, 2001). However, most models from the Psycholinguistics, included those that have been considered here, argue against this total independence, at least during certain stages (see also Plaut, 1997). The fact that in the auditory modality the component presumed to reflect lexical selection exhibits a time course comparable to that of RP but exhibiting a different topography appears to us as an argument favoring our assumption of lexical selection as the process reflected by RP. However, alternative explanations cannot be totally ruled out.

In line with this, it should be commented that when RP has been obtained for pictures, that is, stimuli devoid of word forms, its amplitude has been maximal over the right hemisphere (Hinojosa et al., 2000). However, RP to words systematically exhibits a remarkable left lateralization (e.g. Martín-Loeches et al., 2001a), as was the case here. This fact would harmonize with the assumption that word forms constitute relevant information in the generation of RP.

On the other hand, if RP is affected by context effects during reading, a remaining question that deserves consideration is: why is RP not reported in other studies where similar context manipulations have been performed in reading? As outlined in Section 1, the answer to this question can be approached by considering this situation as the confluence of several circumstances. Its main (though not exclusive) exhibition in a very scarcely used electrode (PO7), the advisable use of a global average reference or, most importantly, the preferable use of the Rapid Stream Stimulation paradigm, could largely explain this state of affairs (Martín-Loeches et al., 2001a; Iglesias et al., in press). Moreover, it must also be considered that the magnitude of the context effects here observed has not been very sizeable (conceivably by the use of the mastoids reference), therefore being probably overlooked if attention is not specifically summoned to this component. The RP is, after all, a highly reproducible component that deserves consideration in the study of language processing by the human brain (Martín-Loeches et al., 1999; Hinojosa et al., 2000, 2001a,b; Martín-Loeches et al., 2001a,b,c), appearing sensitive to sentence context effects.

It should also be commented that, contrary to N400, RP was larger for semantically congruous material. In this regard, it might be commented its resemblance to attentional effects in ERP research. In this line, RP amplitude enhancement might relate to some kind of semantic processing facilitation by contextual information, somewhat like attentional top-down processes. This would substantiate the existence of expected lexical candidates based on the preceding semantic content of the sentence (Friederici et al., 1993), or at least the use of this information to facilitate the processing of an incoming word. In accordance with this, the amplitude of this component presumably related to lexical selection was larger for semantically congruous (and therefore expected) than for incongruous (unexpected) stimuli. This enhancement would therefore reflect context facilitation in order to select the appropriate candidate among those activated during previous lexical access processes (Marslen-Wilson, 1987).

In this regard, RP would behave to some extent resembling more perceptual components in traditional selective attention studies (e.g. Mangun and Hillyard, 1995) in the sense that the brain area generating RP would increase its amplitude to the extent that the stimulus resembles the attended (expected) one. In this case, nevertheless, a primary perceptual property would not be the attended, but rather a conceptual feature. In support of this idea is the fact that congruous ending words were not only semantically congruent with the sentence context but exhibited evident cloze-probability values, whereas incongruous words were never expected. Comparable findings and statements have been reported for N400 by Nobre et al. (1998).

Finally, it must be commented that the interval between two consecutive words of the same sentence was rather long in the present study (750 ms on average). While this was mainly a consequence of introducing background stimuli, it might have induced the use of anticipatory strategies in our participants. Long intervals as those used here, however, are not rare in language ERP research, particularly in N400 studies (e.g. Kutas and Hillyard, 1984; Curran et al., 1993; Johnson and Hamm, 2000), though several N400 studies have revealed the importance of varying the intervals between words (e.g. Deacon et al., 2000; Kiefer and Spitzer, 2000). Accordingly, it appears of interest to perform further research in which stimulus intervals are systematically manipulated in order to explore the role of anticipatory processes on early context effects.

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