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The recognition potential during sentence presentation: stimulus probability, background stimuli, and SOA

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Abstract

Recognition potential (RP) is an electrical brain response that has proved its usefulness for studying semantic processing of isolated words, and appears when subjects view meaningful stimuli embedded in a stream of background images at a high rate of presentation: the rapid stream stimulation paradigm (RSS). The present technical study is aimed at testing the validity of this procedure in the study of words within sentences. For this purpose, we varied word and background probability of appearance, the number of background stimuli preceding each word, and stimulus onset asynchrony. Probability did not have significant effects on RP, but it was found that a minimum number of two background stimuli preceding each word and a high rate (250 ms) of presentation are preferable for enhancing RP amplitude. The RSS paradigm would therefore improve the visibility-and, hence, refine the analysis-of a component that can nevertheless be obtained with more standard paradigms, such as rapid serial visual presentation, devoid of interspersed background stimuli.

Keywords: Language; Recognition potential; Probability; Semantic processing; Sentences; Stimulus onset asynchrony

1. Introduction

Recognition potential (RP) is an electrical brain response peaking approximately 250 ms when subjects view recognizable images, such as words (Rudell, 1991; Rudell and Hua, 1997; Martín-Loeches et al., 1999) or pictures (Rudell, 1992; Hinojosa et al., 2000). It is strongly related to conscious awareness of the stimuli, selective attention being an important factor for evoking it (Rudell and Hua, 1996a).

RP seems to index the processing of word meaning, since 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. Hence, RP amplitude differs as a function of the semantic category of the stimuli (Martín-Loeches et al., 2001a), being

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also larger for concrete than for abstract words (Martín-Loeches et al., 2001b), and for open than for closed-class words (Hinojosa et al., 2001a).

The application of the BESA algorithm has revealed the origin of the activity reflected by RP in basal temporal areas, specifically within the lingual and/or fusiform gyrus (Hinojosa et al., 2000). These areas have been consistently reported as language regions, specifically as related to the processing of semantic features of language (Büchel et al., 1998; Hagoort et al., 1999; Fernández et al., 2001; Giraud and Truy, 2002).

Thus, RP appears as an interesting component, especially considering that the other ERP modulation usually related to semantic information processing has been the N400 (Kutas, 1997; Osterhout and Holcomb, 1995). The N400 is a centrally-distributed negativity, which appears when a semantic incongruence takes place, and can be elicited by either words or pictures (Nigam et al., 1992; Holcomb and Mc Pherson, 1994; Kutas, 1997). However, the N400 presents its peak amplitude at approximately 400 ms after stimulus onset, a time that is certainly considered long for early semantic processing during reading (Rubin and Turano, 1992; Sereno et al., 1998; Perfetti, 1999). Accordingly, RP would be a better candidate than N400 to reflect early semantic processing of words. Indeed, N400 is being considered by some authors as reflecting post-lexical processes (e.g. Karayanidis et al., 1991; Van den Brink et al., 2001)

RP is usually obtained by a procedure called rapid stream stimulation (RSS), developed by Rudell (1992) (see also: Hinojosa et al., 2001c), to some extent similar to the rapid serial visual presentation (RSVP) frequently used in psycholinguistic research. In RSS, however, recognizable (words) and non-recognizable (background) stimuli alternate at a high rate of presentation (usually with a stimulus onset asynchrony – SOA – of 250 ms). Background stimuli are devoid of meaning but with identical physical attributes to those of the word stimuli. Mostly, background stimuli are presented to subjects, and periodically (after at least two to either six or seven background stimuli, this number being randomized) a test stimulus is presented.

RP has shown its utility in the study of semantic processing of isolated words. It would be of great interest, however, to explore its possibilities for the study of semantic processing of words within sentences.

However, the application of the RSS paradigm to the presentation of sentences would constitute a special and apparently unnatural stimulation paradigm, mainly due to the presence of background stimuli alternating with real words, the former also having a greater probability of appearance than the latter. Thus, each word during a sentence presentation is now not an isolated stimulus, but something actually related to previous and subsequent stimuli. It would be under these circumstances that the RSS might appear particularly problematic: there are background stimuli (non-words) between logically (syntactically at least) related words. Further research is therefore needed to clarify the necessity of the RSS paradigm for obtaining an observable RP during sentence presentation. We must explore the extent to which RP is dependent on the particular paradigm used, and whether the RP obtained with such a stimulation paradigm would rather be the enhancement of something that may or may not be obtained with more conventional procedures. The overall aim of the present study is to deal with these questions.

The factors that brought about the development of the RSS are several. First, the rapid rate of image presentation is introduced with the intention of forcing subjects to process the stimuli at regular short time intervals, decreasing the variability between and within subjects when they perform the reading test. Hence, given that stimuli can be (unpredictably) either background stimuli or words, and given that a new visible stimulus will rapidly appear and substitute the current image, it is presumably better for the subject to perform a full and rapid analysis of the stimulus: if lexical information is rapidly accessed (when the stimulus is a word), this information would be stored elsewhere in working memory (e.g. Haarmann et al., 2003), thus overcoming displacements or confusions within the visual working memory store after the rapid-rate image presentation (Rudell, 1992). Subsequently, forcing subjects to perform a fast and complete analysis of each incoming stimulus would, in turn, enhance the electrophysiological signal, since decreasing the processing variability increases the visibility of ERP signals (Picton et al., 1995). This contrasts with the use of more conventional paradigms in which longer SOAs (such as 500 or 1000 ms) are used, where within- and between-subjects variability should be much greater.

Second, the concept of the presence of background stimuli was originally introduced by Rudell (1991), in order to avoid or reduce visual related components such as the N1-P2 complex, as their latency largely overlaps with RP. Accordingly, the background stimuli act as preempt stimuli by temporally usurping activity in the visual afferent pathway. Thus, a second image presented immediately or a very short time later appears in the aftermath of activity evoked by the preempt stimulus, which by leaving some elements of the brain in a refractory state prevents the second image from fully developing its normal electrophysiological response (Rudell, 1991).

Third, background stimuli are always presented between words, that is, two words are never presented consecutively, presumably because RP to the second word would be overlapped and contaminated by components subsequent to the previous stimulus. In this regard, it can be mentioned that immediately after the appearance of RP, there is a subsequent component of inverse polarity, peaking at approximately 470 ms after stimulus onset and displaying a similar distribution (Martín-Loeches et al., 2001a). This would occur at approximately the same time as an RP to a following word using this rate of presentation. The paradigm, therefore, would require the presence of at least one background stimulus before each word is presented. However, it seems possible that other deflections could also follow or overlap with the subsequent component, that is, slow waves or long-latency language-related components (e.g. Friederici, 1999), and this is presumably why a minimum of two background stimuli should precede each word. These claims should, nevertheless, be subjected to further confirmation.

Also, the number of background stimuli cannot be fixed to either one or two, since the appearance of a word stimulus has to be unpredictable to subjects. Otherwise, implementing a rapid rate of presentation would be useless, as the subjects could displace their attention during the appearance of background stimuli, reallocating attention only when target stimuli were going to appear. This is the reason why the number of background stimuli between words is usually randomized from two to six. This, in turn, results in a lower probability of word appearance. Words being the target stimuli, it seems plausible that RP could be rather reflecting processes that depend on- or are affected by-probability of occurrence, such as P300-like responses. As is well known, less probable target stimuli produce larger P300 amplitudes than more frequently-occurring targets (Tueting et al., 1971; Duncan-Johnson and Donchin, 1977). Although it is fairly clear that RP and P300 phenomena are unrelated (Rudell, 1991), and that the sensitivity of RP to semantic features rules out its consideration as a purely probability-related component, it seems necessary to further clarify the extent to which stimulus probability is contributing to RP.

The reason for inserting background stimuli between words is, therefore, to avoid presumable contamination of RP by components subsequent to preceding words, but it appears plausible that by increasing the SOA to 500 or even 1000 ms, overlapping phenomena could also be prevented. Even so, as already mentioned, short SOAs are preferable. In any case, it is important to further explore the extent to which short SOAs are really necessary for obtaining a visible RP.

Accordingly, two sets of experiments are presented here. In the first one, the probability of occurrence of words and background stimuli is systematically varied. The effect of the presence of background stimuli preceding each word within different conditions of probability is also explored. In the second experimental series, two variables are systematically examined: the specific number of background stimuli that precede each word, and the SOA when only words are presented. Every manipulation described here is made within the context of sentence presentation, as the main purpose of the present work is to evaluate the validity of our conclusions in the procurement of RP during sentence processing.

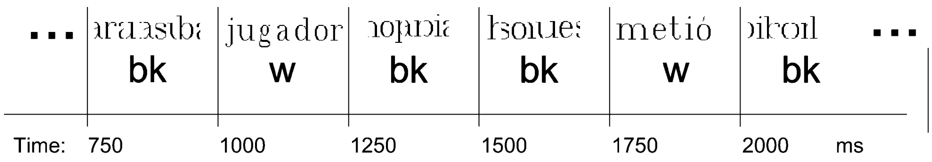

Fig. 1. Sample of the stimulation procedure. 'W' refers to words, whereas 'bk' refers to background stimuli. Words appeared following a variable number of background stimuli until a sentence was completed.

2. Experiment 1: effects of stimulus probability and the presence of background stimuli

2.1. Methods

2.1.1. Subjects

Twenty-eight subjects (three males) ranging in age from 18 to 22 years (mean = 18.75) participated in the study. All of them were right-handed with average handedness scores (Oldfield, 1971) of +81, ranging from +33 to +100. All were native Spanish speakers and had normal or corrected-to-normal vision.

2.1.2. Stimuli

A total of 73 transitive sentences were used. Structure of the sentences was as follows: article-subject-verb-article-object. All verbs were regular and conjugated in the past tense. Words were constructed in lower case letters with the exception of the first letter of the first word, which was an upper case letter. The final word of each sentence was accompanied by a period in order to mark the end of the sentence for the subjects. With the exception of articles, 63% of words were two-syllable and 37% were three-syllable.

As in previous RP research, a pool of 144 background stimuli was also constructed by cutting 144 randomly-selected real words (excluding articles) into '*n*' portions (*n* = number of letters composing a word minus one). The last piece of each word was placed in the first position of the new stimulus, and vice versa; and so on. Thus, each stimulus had, at least, two complete letters, but also clearly identifiable non-letters (resulting from the fusion of different letter fragments). A depiction of the appearance of background stimuli can be seen in Fig. 1. Although this method for constructing non-word stimuli is not the most standard in psycholinguistics, where consonant strings are usually employed, it was preferred here, as this type of stimulus is actually used as standard controls in RP research (Martín-Loeches et al., 1999). Even so, neither non-words formed by consonant strings nor those used here would presumably yield substantial differences (Martín-Loeches et al., 1999, 2001a).

Both types of stimuli (words and background) were thus matched in visual aspects. They were presented white-on-black on an 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.

2.1.3. Procedure

All subjects performed in four experimental conditions. In Condition 1, only background stimuli were presented (and hence, probability of background = 100%; probability of word = 0%). In Condition 2, only words embedded in sentences were presented (probability of background = 0%; probability of word = 100%).

Conditions 3 and 4 were formed by combining words and background stimuli. In Condition 3 the probability of word appearance was 25% (background probability = 75%), whereas in Condition 4 the probability of word appearance was 75% (background probability = 25%).

From the total set of 73, sentences were randomly assigned without repetition to Conditions 2 to 4 until a minimum of either 50 words or 50 background stimuli could be obtained in each condition in order to provide a valid number of epochs during EEG recordings, considering that articles were ignored in the analyses – so that only three words per sentence could be employed, i.e. nouns as subjects, nouns as objects, and verbs. In accordance with this procedure, 20 sentences were assigned to Condition 2 (yielding 60 word stimuli when ignoring articles), 17 to Condition 3 (51 words when omitting articles, most being background stimuli), and 36 to Condition 4 (51 background stimuli, most being words). The different number of sentences was determined by the probability of occurrence of either words or background stimuli within each condition, considering the total duration of each condition. This is best illustrated by considering the case of Conditions 3 and 4. By equating the number of sentences used in either of these conditions while respecting the probability constraints, the duration of Condition 3 should be notably longer than that of Condition 4, as the proportional number of background stimuli to attain a word probability = 25% in Condition 3 would remarkably lengthen its duration. Finally, a total of 100 background stimuli were presented during Condition 1 (probability of background = 100%) in order to harmonize with the total number of stimuli (that is, including articles) appearing during its counterpart condition (Condition 2; probability of word = 100%).

Within each condition, the SOA was always 250 ms and there was no interstimulus interval (ISI). In Conditions 2, 3 and 4, sentences were presented one word at a time. Similarly, in Condition 1, one background stimulus was presented at a time. Additionally, each stimulus within Conditions 3 and 4 could be either a background stimulus or a word (here, background stimuli were interspersed between words belonging to the same sentence), and the appearance of either type was determined randomly but always following the probability constraints intrinsic to each condition. In contrast to the standard RSS paradigm, the constraint that two words could never appear consecutively was not followed in the present experiment, as probability was the main manipulation here.

Presentation order of the conditions was systematically varied according to a Latin-square design. Before each of the experimental conditions a practice block including none of the experimental sentences was presented to participants. Except in Condition 1, participants were instructed to read the experimental sentences for comprehension and to answer questions when required. For Condition 1, they were asked to watch the background stimuli stream carefully because a word could appear, and to count the number of words they could see, in order to maintain their attention. At the beginning of each condition, a message on the screen requested subjects to blink as much as they needed, in order to avoid doing so as far as possible during stimuli presentation (although an ocular artefact correction method was subsequently used), and to push a button to start the condition.

Except for Condition 1, every four to six sentences (this number randomized) subjects were presented with a comprehension test question about the contents of the immediately preceding sentence. Half of the questions required an affirmative response, and the rest required a negative one.

2.1.4. Electrophysiological recordings

Continuous EEG was recorded from 58 scalp electrodes. 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 embedded in an electrode cap (Electro-Cap International), and left mastoid (M1), all referenced against the right mastoid (M2). The 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.

The vertical electrooculogram (VEOG) was recorded from below vs. above the left eye, whereas the horizontal electrooculogram (HEOG) was recorded from positions at the outer canthus of each eye. 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 0.3–50 Hz bandpass.

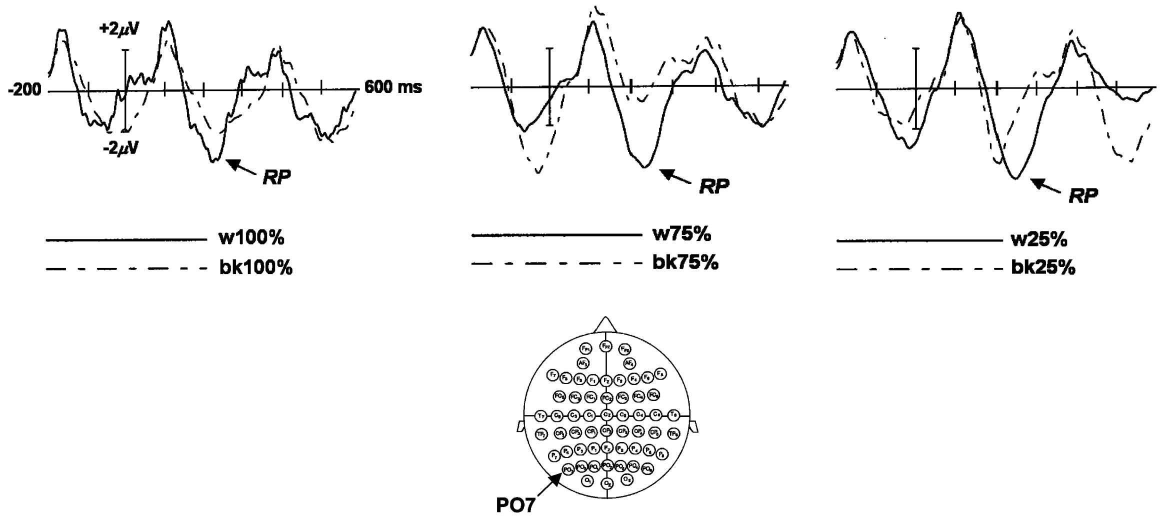

Fig. 2. Grand-averaged ERP at PO7 Electrode. A clear Recognition Potential (RP) can be identified for words as compared to background stimuli at each level of probability: 100% (left), 75% (middle) or 25% (right).

2.1.5. Data analysis

EEG epochs were extracted starting 200 ms before and lasting 1024 ms after the presentation of each stimulus.[1] For each condition, a selection of epochs was performed in order to include only certain epochs in the averages. For Condition 1 (probability of background = 100%), 60 out of the 100 stimuli were randomly selected, in order to match the number of stimuli employable in Condition 2 (probability of word = 100%). For Condition 3 (probability of word = 25%) the total 51 words were used, while 51 out of 255 background stimuli were randomly selected. For Condition 4 the total 51 background stimuli were used, whereas 51 out of 108 employable words were randomly selected.

All selected epochs were evaluated individually for EOG or other artefacts, contaminated trials being excluded from the averaging procedure. Also, off-line correction of small eye-movement artefacts was 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 whole sample of cephalic electrodes, which has proved to be the best procedure to obtain RP (Martín-Loeches et al., 2001a). ERP averages were aligned to a −200 ms pre-stimulus baseline and computed separately for each condition, as well as for each type of stimulus.

2.2. Results

Performance in the comprehension test questions was virtually perfect: 100% of correct responses in Conditions 1, 2 and 4 and 99% in Condition 3, which indicates that subjects were correctly performing the sentence comprehension task, as well as the task required in Condition 1: no subjects saw any word in the stream of 100% background stimuli.

A negative wave (RP) peaking maximally at PO7 was obtained for words, whereas background stimuli displayed greatly reduced activity in this period (Fig. 2). RP amplitude and peak latency values at Conditions 2, 3 and 4 were, respectively: −3.4 µV and 240 ms, −4.4 µV and 252 ms, and −4 µV and 232 ms.

[1] With this procedure, both the baseline and the poststimulus period could include some activity related to previous or subsequent stimuli. This not unusual situation in ERP research (e.g., Kutas, 1987; Hagoort and Brown, 2000) is nevertheless controlled by considering that this occurs similarly across conditions.

An ANOVA comparing RP peak latencies at PO7 electrode with word probability of occurrence as repeated-measures factor yielded non-significant results ($F_{2,54}=1.6$; $P=0.214$; $\varepsilon=0.682$), so that the same peak latencies could be assumed across the different levels of word probability. A narrow window was established centered on the overall mean peak amplitude (240 ms), with the purpose of measuring amplitude for statistical analysis. This window extended from 212 to 268 ms (around mean ± 28 ms) after stimulus onset.

To avoid a loss of statistical power when repeated-measures ANOVAs are employed to quantify a large set of electrodes (Oken and Chiappa, 1986), analyses were conducted on a selected sample of 30: Fp1, Fp2, AF3, AF4, F5, F1, F2, F6, FC5, FC1, FC2, FC6, C5, C1, C2, C6, CP5, CP1, CP2, CP6, P5, P1, P2, P6, PO7, PO1, PO2, PO8, O1 and O2 (for an extended justification of these procedures, see Martín-Loeches et al., 1997).

A three-way ANOVA was then performed with three repeated-measures factors: type of stimulus (two levels: words and background), probability (three levels: 25, 75 and 100%), and electrode (30 levels).

Significant results with the Greenhouse–Geisser correction were obtained for type of stimulus ($F_{1,27}=8.9$; $P=0.006$; $\varepsilon=1$) as well as electrode ($F_{29,783}=42.1$; $P<0.0001$; $\varepsilon=0.089$), but not for probability ($F_{2,54}=2.2$; $P>0.1$; $\varepsilon=0.647$). Significant results were also obtained in the interactions type of stimulus by electrode ($F_{29,783}=22.8$; $P<0.0001$; $\varepsilon=0.127$), probability by electrode ($F_{58,1566}=5.3$; $P<0.0001$; $\varepsilon=0.093$) and type of stimulus by probability by electrode ($F_{58,1566}=3.9$; $P<0.0001$; $\varepsilon=0.137$); interaction between type of stimulus and probability yielded non-significant results ($F_{2,54}=1.9$; $P>0.1$; $\varepsilon=0.604$).

In order to prevent type I error (e.g. Sankoh et al., 1997; Perneger, 1998), and for the sake of simplicity, post-hoc analyses on RP amplitude with the Bonferroni correction were performed only for the electrode showing the highest amplitude (PO7). Pair-wise ANOVAs with probability of word appearance as factor yielded significant results when comparing 100 and 75% of word probability ($F_{1,27}=7.9$; $P<0.05$), as well as 100 and 25% of word probability ($F_{1,27}=13.5$; $P<0.01$), whereas comparisons between 25 and 75% did not reveal a significant difference ($F_{1,27}=4.4$; $P>0.1$).

Post-hoc analyses with the Bonferroni correction also showed significant differences in the electrical response to words and background stimuli at the same level of probability, that is, when comparing Conditions 1 and 2 (100%) ($F_{1,27}=8.6$; $P<0.01$), when comparing words in Condition 3 and background in Condition 4 (25%) ($F_{1,27}=31,7$; $P<0.01$), and when comparing words in Condition 4 and background in Condition 3 (75%) ($F_{1,27}=89.1$; $P<0.01$)[2].

Overall, these results can be summarized by saying that RP can be obtained even under conditions of word probability = 100%, that is, even in the total absence of background stimuli. However, probability seems to influence RP amplitude, by reducing its values when word probability = 100%. However, there is an additional variable that could explain these effects of probability, and that could be confounding the present design.

When comparing RP to words at different levels of probability, only Condition 2, in which just words were presented, was significantly different from the other two conditions. If probability alone were a crucial factor, RP to words in Conditions 3 (25%) and 4 (75%) should significantly differ, and this was not the case. At this point, it appeared plausible that it was not the probability of word as such that was the variable explaining these results, but rather a related variable, intrinsic to this design, and whose importance was already stated in Section 1. We are referring to the existence of background stimuli preceding words, a variable that can be controlled with the present design.

Accordingly, we conducted new analyses in Conditions 3 and 4, with the aim of comparing

[2] Activity to backgrounds is normally used as a control to be removed from the waveforms to words (Hinojosa et al., 2001c), and this is why between-backgrounds comparisons as a function of probability are not pertinent, Nevertheless, it is true that on this occasion backgrounds seemed to display a relatively appreciable ‘RP-like’ activity. Even so, these apparent effects were not only far from systematic (amplitude decreases from 100 to 75%, but increases from 75 to 25%), but also failed to be maintained after statistical comparisons.

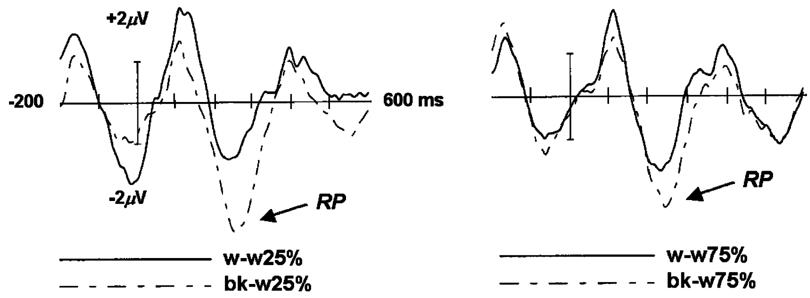

Fig. 3. Grand-averaged ERP at PO7 Electrode separated as a function of the type of preceding stimulus for 25% (left) and 75% word probability (right). RP amplitude was maximum for words when they were preceded by background stimuli at either level of probability.

RP amplitude as a function of the type of preceding stimulus. Both types of stimulus (words and background) were therefore separated as a function of their preceding stimulus, yielding the following situations: word immediately preceded by a word in condition of 25% of word probability (w-w25%), word immediately preceded by a background stimulus at the same probability (bk-w25%); word immediately preceded by a word in condition of 75% of word probability (w-w75%) and, finally, word immediately preceded by a background stimulus at this level of probability (bk-w75%).

Latency and amplitude average values at PO7 electrode (Fig. 3) were as follows: w-w25% = −2.8 μV, 244 ms; bk-w25% = −6.3 μV, 260 ms; w-w75% = −3.4 μV, 220 ms; and bk-w75% = −5.1 μV, 236 ms. An ANOVA with the Greenhouse–Geisser correction was performed, comparing RP peak latencies, and in which word probability of occurrence (25 and 75%) and preceding stimulus (word or background) were explored as factors. Both factors yielded significant results: probability ($F_{1,27}=22.9$; $P<0.0001$; $\varepsilon=1$) and preceding stimulus ($F_{1,27}=15.2$; $P<0.001$; $\varepsilon=1$). However, the interaction between the two factors was not significant ($F_{1,27}=0.7$; $P>0.1$; $\varepsilon=1$). Subsequently, further ANOVAs with the Bonferroni correction were carried out to compare latencies pair-wise. Significant results were obtained in the following comparisons: w-w25% and w-w75% ($F_{1,27}=18.5$; $P<0.0001$), bk-w25% and bk-w75% ($F_{1,27}=14{,}5$; $P=0.0001$); as well as bk-w25% and w-w 25% ($F_{1,27}=7.951$; $P=0.009$) and bk-w75% and w-w75% ($F_{1,27}=7.368$; $P=0.011$). Accordingly, for statistical amplitude analyses different windows were assumed, centered on their respective mean peak latencies: w-w25% (216-272 ms), bk-w25% (232-288 ms), w-w75% (192-248 ms) and bk-w75% (208-264 ms).

Amplitude data were subjected to a 2×2×2×30 repeated-measures ANOVA, the factors being: type of stimulus (word and background), preceding stimulus (word and background), probability (25 and 75%) and electrode (the same sample of 30 electrodes as used in the former analysis).

Probability was not significant either alone ($F_{1,27}=0.2$; $P>0.1$; $\varepsilon=1$) or interacting with type of stimulus ($F_{1,27}=0.5$; $P>0.1$; $\varepsilon=1$), preceding stimulus ($F_{1,27}=0.2$; $P>0.1$; $\varepsilon=1$), or type of stimulus and preceding stimulus simultaneously ($F_{1,27}=0.3$; $P>0.1$; $\varepsilon=1$). However, probability was significant when interacting with electrode ($F_{29,783}=4.1$; $P<0.01$; $\varepsilon=0.173$). Also, the interaction between probability, preceding stimulus and electrode ($F_{29,783}=11.5$; $P<0.0001$; $\varepsilon=0.122$) was significant, as was the interaction between probability, type of stimulus and electrode ($F_{29,783}=5$; $P<0.0001$; $\varepsilon=0.124$). Type of stimulus was significant alone ($F_{1,27}=11.1$; $P=0.002$; $\varepsilon=1$), interacting with electrode ($F_{29,783}=24.7$; $P<0.0001$; $\varepsilon=0.123$), and interacting with preceding stimulus and electrode ($F_{29,783}=5.3$; $P>0.01$; $\varepsilon=0.088$). Preceding stimulus showed a

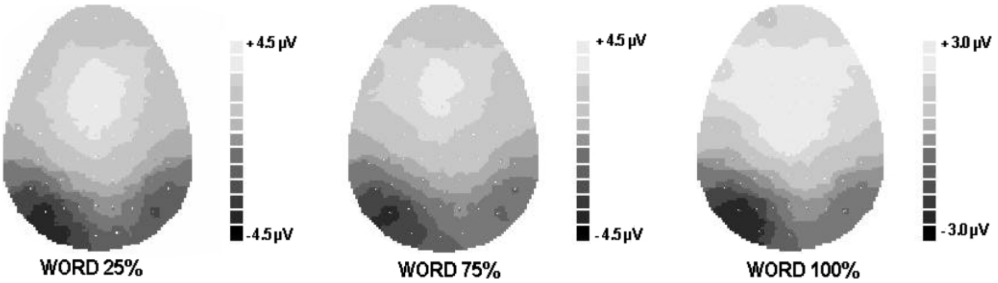

Fig. 4. Topography of RP across the total array of 60 cephalic electrodes at each level of word probability. The maps represent values for the time window from 212 to 268 ms. The topography of all the maps is remarkably similar, consisting in a left-lateralized parieto-occipital negativity and a widely distributed positivity over fronto-central regions. Note that individual color scales for amplitude values have been used.

statistical trend to significance alone ($F_{1,27}$=3,2; $P<0.1$; $\varepsilon=1$), whereas it was not significant interacting with type of stimulus ($F_{1,27}=0.5$; $P>0.1$; $\varepsilon=1$), being significant when interacting with electrode ($F_{29,783}=8.8$; $P<0.0001$; $\varepsilon=0.107$). Electrode was significant alone ($F_{29,783}=36.5$; $P<0.0001$; $\varepsilon=0.074$). Finally, the interaction between the whole sample of factors was not significant ($F_{29,783}=1$; $P>0.1$; $\varepsilon=0.082$).

Post-hoc analyses with the Bonferroni correction were performed to compare amplitude differences pair-wise. Significant results were obtained when comparing w-w25% and bk-w25% ($F_{1,27}=31.9$; $P<0.01$), and when comparing w-w75% and bk-w75% ($F_{1,27}=18.6$; $P<0.01$), but not when comparing bk-w25% and bk-w75% ($F_{1,27}=5.8$; $P>0.1$) or w-w25% and w-w75% ($F_{1,27}=2.7$; $P>0.1$). This indicated a main effect of preceding stimulus on amplitude at the same level of probability, disregarding a probability effect with a similar preceding stimulus. Accordingly, previous effects of probability in the original ANOVA – when Conditions 2, 3, and 4 were considered simultaneously-could be mainly attributed to the type of preceding stimulus.

Finally, the maps for RP (that is, only to word stimuli) in the 212–268 ms period are displayed in Fig. 4. Maps show a highly similar topography in all three-word probability conditions, and which consists in a left inferior-parietal negativity and a positive counterpart over fronto-central regions. A profile analysis (McCarthy and Wood, 1985) confirmed this similarity. For the time window of interest (212–268 ms), 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, provide unambiguous evidence for different scalp distributions. An ANOVA was therefore performed on these scaled data with word probability (3 levels: 25, 75, and 100%) and electrode (30) factors. This yielded no significant results either for the probability factor or in the probability by electrode interaction ($F_{2,54}=0.006$; $P>0.1$; $\varepsilon=0.567$; $F_{58,1566}=1.03$; $P>0.1$, $\varepsilon=0.103$, respectively). Accordingly, we can conclude not only that RP can be obtained in the total absence of background stimuli, but also that background stimuli do not affect its topography at all.

2.3. Discussion

The present data show that RP can be obtained to meaningful stimului independently of its probability of appearance and of the presence of interspersed background stimuli. Words always showed higher RP amplitude than stimuli devoid of meaning, which confirms its sensibility to linguistic features, as previous research has already highlighted (Rudell, 1991, 1992; Rudell and Hua, 1997; Martín-Loeches et al., 1999; Hinojosa et al., 2000, 2001a,b; Martín-Loeches et al., 2001a,b). Also, RP showed identical scalp distribution independently of word probability and of the presence of background stimuli, providing additional support for the idea that probability as well as the presentation of backgrounds in the stream of stimulation has little impact, if any, on the processes reflected by RP, an impact that in the best case can be described as a mere amplitude enhancement, but never a condition necessary for attaining an RP. This statement validates RP as a linguistic component, independently of the particular paradigm usually employed to obtain it.

Probability effects were found on amplitude in the overall ANOVA analyses. However, post-hoc analyses for the PO7 electrode, where RP manifests its maximum amplitude, failed to support a significant effect of probability on RP when the type of preceding stimulus was controlled – that is, when only Conditions 3 and 4 were considered. This can be clarified by looking at Fig. 3. There, small differences between RP amplitudes under different conditions of probability could be suspected, but these differences are not consistent. However, we have the fact that RP amplitude appears larger for words preceded by background stimuli when word probability is 25%. However, when considering words preceded by a word, effects of probability would go in the opposite direction. Furthermore, neither of these two inconsistent differences reached statistical significance. Consequently, effects of probability on RP seem neither consistent nor supported statistically, leading us to the conclusion that RP appears insensitive to probability.

The only consistent result is the type of preceding stimulus: words preceded by background stimuli always display larger RP amplitudes than words preceded by words, and this is the main effect that remained significant.

Hence, when a background stimulus is presented before a word, RP shows its maximum values, confirming our hypothesis that background stimuli enhance RP amplitude by avoiding the overlapping of ERP fluctuations related to previous stimuli. Given that the electrical response to background stimuli is of short duration and lower intensity, RP cannot be overlapped by its preceding stimulus. It is assumed, then, that the amplitude reduction in RP observed when only words are presented (Condition 2)—indeed, an RSVP paradigm—is the result of some degree of overlapping by electrophysiological fluctuations linked to the preceding word stimulus.

Some comment should be made on the effects of probability and preceding stimulus on RP latency. The response was earlier with higher levels of word probability, as well as when the preceding stimulus was another word. These effects may be due to different phenomena, and they did not actually interact. Probability effects on latency can be explained by expectation processes. Expected stimuli are processed faster than unexpected ones (e.g. Posner, 1990), and the more probable a stimulus, the more expectable it becomes. However, the effect of preceding stimulus on RP latency may be in line with RP latency decreases when a prime stimulus is presented before a target stimulus (Rudell and Hua, 1996b) although, alternatively and complementarily, a task-switch effect could also suggested for explaining a latency increase when a word is preceded by a background stimulus (Allport and Wylie, 2000).

Consequently, the principal conclusion of the first experimental series is that the main variable for best perceiving RP amplitude is the presence of background stimuli preceding word stimuli, but that the RP obtained when background stimuli are interspersed does not differ qualitatively from the RP obtained under more normal stimulation paradigms, such as the RSVP. The presence of background stimuli would enhance the visibility of RP amplitude by removing from the recordings electrophysiological fluctuations linked to preceding words. If this were the case, as indeed it seems to be, then two further manipulations would definitely help to give a better picture of the situation.

However, we need to know the minimum number of background stimuli preceding each word necessary to attain an RP free of contamination. Indeed, by interspersing one background before each word, a large amount of overlapping can be avoided. However words, and especially words within sentences, can evoke low-duration potentials that may contaminate the activity to words presented even 600–800 ms later (e.g. Friederici, 1999), that is, even to words appearing after an interspersed background stimulus. However, it is necessary to determine to what extent an SOA increase could minimize the overlapping of electrophysiological fluctuations due to preceding stimuli. With longer SOAs, contamination must decrease. However, as mentioned in the introduction, short SOAs are presumably preferable for enhancing RP amplitude. Nevertheless, it appears pertinent to explore the extent to which short SOAs are really necessary to obtain a visible RP. These two manipulations are conducted in the second experimental set.

3. Experiments 2 and 3: effects of the number of preceding background stimuli and SOA

3.1. Methods

3.1.1. Subjects

A different sample of twenty-two subjects (one male) participated in this study. Mean age was 20.2 years (range 18–22). All participants were right-handed, with average handedness scores (Oldfield, 1971) of +74, ranging from +11 to + 100. All had normal or corrected-to-normal vision and were native Spanish speakers.

3.1.2. Stimuli and procedure

Experiments 2 and 3 were performed during the same recording session. Experiment 2 involved the manipulation of the number of background stimuli preceding each word, and consisted in a single condition. For this condition, 38 out of the 73 sentences used in Experiment 1 were randomly selected, this number being determined to obtain an appropriate number of epochs. The words could be preceded by any number of background stimuli, always with a minimum of 1 and a maximum of 8, and the probability of finding a certain number of preceding background stimuli was kept constant. The complete pool of background stimuli from Experiment 1 was used here. Stimuli were again presented with an SOA of 250 ms and no ISI.

Experiment 3 involved the manipulation of SOA. It had two conditions, each one created using a different pool of 10 sentences randomly selected without repetition from the 73 sentences used in Experiment 1, and excluding also those used in Experiment 2. No background stimuli were used. SOA was 500 ms in Condition 1 and 1000 ms in Condition 2, both again with no ISI.

Before Experiment 2 and before each one of the experimental conditions in Experiment 3, a practice block was presented to participants. Instructions to subjects were to read the sentences for comprehension and answer questions as required. As in Experiment 1, every four to six sentences (this number being randomized), subjects were presented with a question about the contents of the immediately preceding sentence; half of the questions required an affirmative response and the rest required a negative one.

At the beginning of Experiment 2 and of each condition in Experiment 3, a message on the screen asked participants to blink in order to avoid doing so during stimuli presentation, and to push a button to start the condition.

All subjects performed Experiment 2 (one condition) and the two conditions of Experiment 3, presentation order being varied according to a Latin-square design.

3.1.3. Electrophysiological recordings and data analysis

Continuous EEG was recorded and analyzed following the procedures in Experiment 1. ERP averages were computed separately for each type of stimulus (words and background), as well as for each condition in Experiment 3. The sample of words analyzed in the three conditions had, as in Experiment 1, equivalent proportions of nouns as subjects, nouns as objects, and verbs.

In Experiment 2, words were separated depending on certain numbers of preceding background stimuli: 1 background (1bk-w), 2 (2bk-w), 4 (4bk-w) or 8 (8bk-w), disregarding other possibilities (e.g. 3, 5, 6, or 7 backgrounds). In the same way, control background stimuli were computed separately depending on the number of preceding background stimuli: 1 (1bk-bk), 2 (2bk-bk), 4 (4bk-bk) and 7 (7bk-bk) – seven was the largest number of preceding background stimuli for backgrounds, therefore functionally equivalent to 8bk-w. Analyses in Conditions 2 and 3 followed the same procedures as for Condition 2 in Experiment 1.

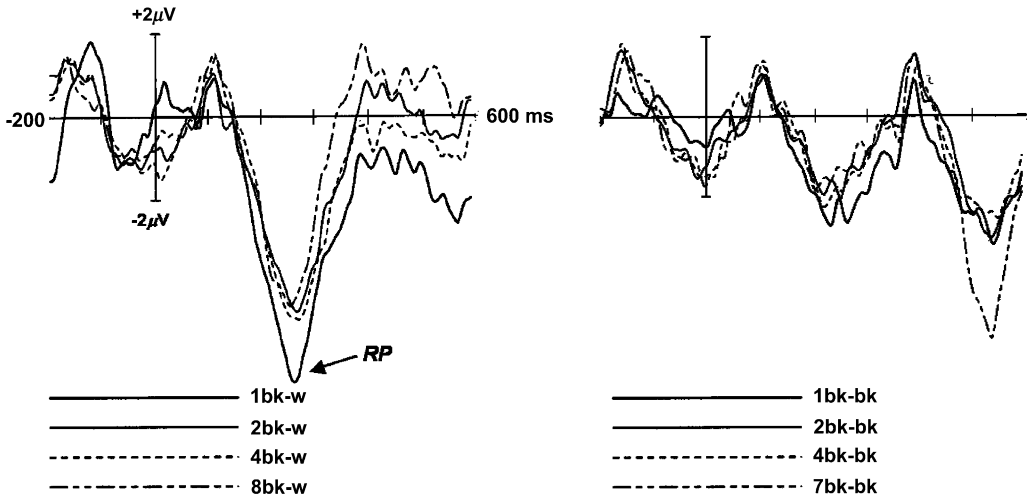

Fig. 5. Grand-averaged waveforms at PO7 electrode for words (left) and background (right) separated as a function of the number of preceding background stimuli. RP can be observed for words, displaying higher amplitude when only one background stimulus preceded the word.

3.2. Results

Performance in the comprehension test questions for Conditions 1 and 2 of Experiment 3 was perfect: 100% of correct responses, indicating the simplicity of the task; in Experiment 2 error rate was also practically negligible: 1.42%.

3.2.1. Experiment 2: effects of the number of preceding background stimuli

Again, a negative wave (RP) peaking maximally at PO7 electrode was obtained for words (Fig. 5). Amplitude and peak latency values as a function of the number of preceding background stimuli was as follows: 1bk-w, −6.3 μV and 260 ms; 2bk-w, −4.6 μV and 264 ms; 4bk-w, −4.8 μV and 268 ms; 8bk-w, −4.5 μV and 248 ms. Accordingly, RP appeared larger for words preceded by one background stimulus, whereas the remaining possibilities displayed highly similar amplitude values. Fig. 5 also shows the results for background stimuli as a function of the number of other preceding backgrounds, displaying greatly reduced activity throughout the RP period. An RP-like activity approximately 500 ms for 7bk-bk is indeed an RP for the word that necessarily follows 250 ms after the onset of that background stimulus – the latest possible. An ANOVA with the Greenhouse–Geisser correction to compare latencies yielded significant results ($F_{3,63}=3.4$; $P<0.05$; $\varepsilon=0.839$), although post-hoc comparisons with the Bonferroni correction only reached significance when comparing 4bk-w and 8bk-w ($F_{1,21}=9.8$; $P<0.01$).

An ANOVA on RP amplitude was performed assuming the following time intervals centered on the mean peak amplitude (±28 ms), depending on the number of preceding background stimuli for words: 1bk-w (232–288 ms), 2bk-w (236–292 ms), 4bk-w (240–296 ms) and 8bk-w (220–276 ms)[3]. This ANOVA, conducted with the same sample of electrodes as that of Experiment 1, had three factors: type of stimulus (with two levels: words and background stimuli), number of preceding background stimuli (four levels: 1, 2, 4, or the largest possible value – 8 for words, 7 for backgrounds), and Electrode (30).

Significant results with the Greenhouse–Geisser correction were obtained for type of stimulus

[3] Time windows are always based on RP to words, as BKs usually show irregular or noisy activity, or none at all, for the RP period. In this case, the time window for 8bk-w was applied to 7bk-bk, though only after verifying that their peak latencies did not significantly differ.

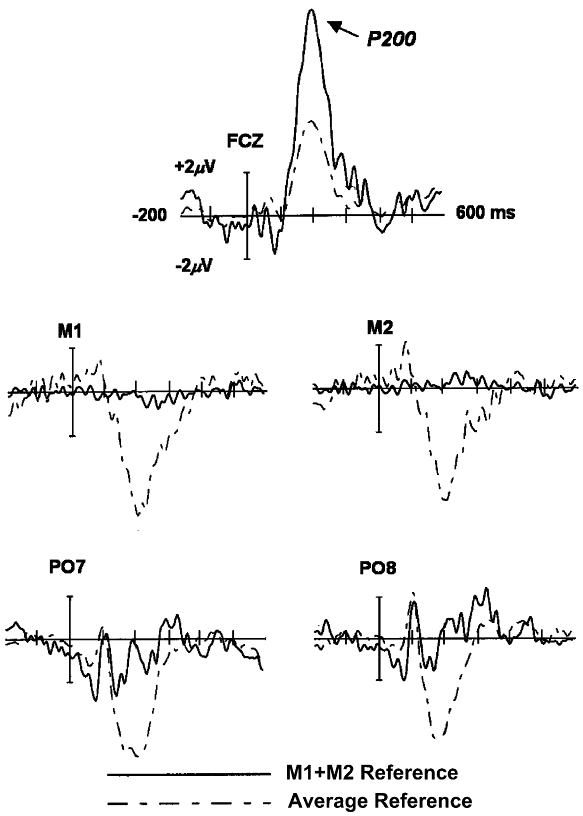

Fig. 6. Grand-averaged waveforms for words in the absence of background stimuli with an SOA of 500 ms in a selected sample of electrodes. A remarkable P200 can be observed at FCZ, being maximal when employing M1 + M2 reference. When employing the average of the whole sample of electrodes as reference, we obtained identical results to those with the SOA of 1000 ms: P200 at FCZ was attenuated, whereas M1 and M2 showed the highest values in the time window where RP should appear.

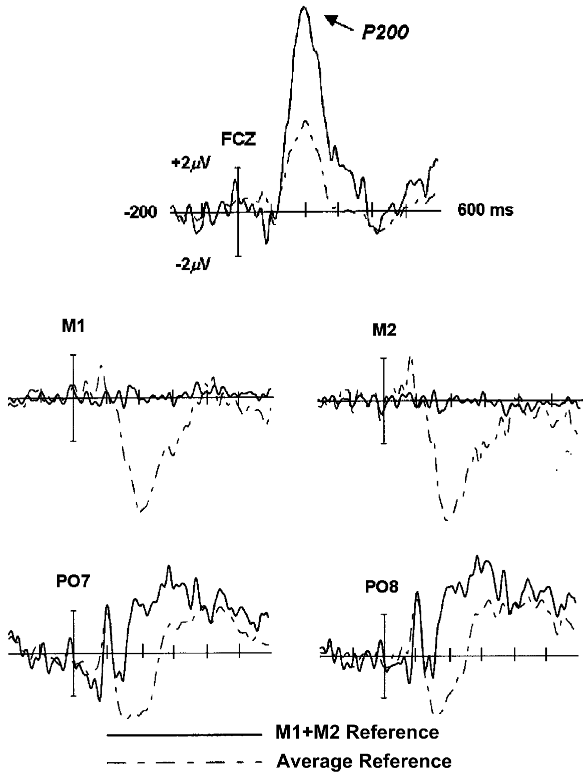

Fig. 7. Grand-averaged waveforms for words in the absence of background stimuli with an SOA of 1000 ms. Again, a remarkable P200 can be observed at FCZ, being maximal with M1 + M2 reference. When employing the average of the whole sample of electrodes as reference, identical results to those with an SOA of 500 ms were obtained: P200 at FCZ was attenuated, whereas M1 and M2 showed the highest values in the time window of RP.

($F_{1,21} = 38.4$; $P < 0.0001$; $\varepsilon = 1$), electrode ($F_{29,609} = 44.7$; $P < 0.0001$; $\varepsilon = 0.174$), and the interactions between type of stimulus and electrode ($F_{29,609} = 37.10$; $P < 0.0001$; $\varepsilon = 0.127$) and between number of preceding background stimuli and electrode ($F_{87,1827} = 3.2$; $P < 0.01$; $\varepsilon = 0.07$), and type of stimulus by number of preceding background stimuli by electrode ($F_{87,1827} = 7.3$; $P < 0.0001$; $\varepsilon = 0.066$). Number of preceding background stimuli was not significant alone ($F_{3,63} = 2.6$; $P > 0.1$; $\varepsilon = 0.882$), and nor was the interaction between number of preceding background stimuli and type of stimulus ($F_{3,63} = 1.7$; $P > 0.1$; $\varepsilon = 0.829$). Post-hoc analyses with the Bonferroni correction at PO7 revealed significance only when comparing 1bk-w with all other possible combinations: 2bk-w ($F_{1,21} = 16.9$; $P < 0.001$), 4bk-w ($F_{1,21} = 10.8$; $P < 0.01$), and 8bk-w ($F_{1,21} = 11.4$; $P < 0.01$).

The results can be summarized, therefore, by stating that RP seems to be largest when only one background stimulus precedes a word, whereas the rest of numbers of preceding backgrounds yield comparable results, that is, a valid RP, but with lower amplitude.

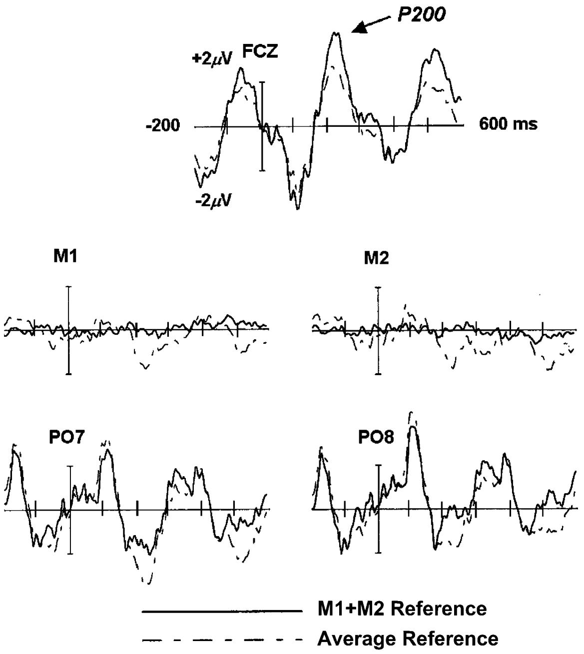

Fig. 8. Grand-averaged waveforms for words in the absence of background stimuli with an SOA of 250 ms in a selected sample of electrodes (from Experiment 1, Condition 2). A notably reduced P200 can be observed at FCZ with either reference method, and especially with the average-reference method.

3.2.2. Experiment 3: effects of SOA

Figs. 6 and 7 show the results corresponding to Conditions 1 and 2 of the present experiment, respectively. For comparison purposes, the results of Condition 2 from Experiment 1 are shown in Fig. 8 in a comparable manner. Also, in the three figures, both the average reference and the linked mastoids reference of the same results are shown, as this will greatly help in the interpretation of the results.

By considering the average referenced data alone, the first thing that can be observed is that when the SOA is either 500 or 1000 ms, the presumed RP component—a conspicuous posterior negativity approximately 250 ms—does not display the typical distribution, usually maximal at PO7, that can nevertheless be appropriately observed with SOA 250 (Fig. 8). Rather, a bilateral mastoids maximum is now observed. The timing is also not typical of RP, as it was 200 ms for SOA 500 and 196 ms for SOA 1000, whereas 240 ms for SOA 250 approaches the most typical values.

According to the timing and distribution of the data, it seemed clear to us that these new results with longer SOAs might rather be the consequence of contamination by another conspicuous component peaking approximately 200 ms. The best candidate for this was the fronto-central P200, and indeed this component appeared highly evident when using a mastoids reference. With this reference, it can be observed that longer SOAs (500 and 1000 ms) display a notably large P200 component at fronto-central positions, whereas this component is remarkably reduced when the SOA is of 250 ms.

3.3. Discussion

3.3.1. Effects of the number of preceding background stimuli

Results showed that RP seems to be largest when only one background precedes a word, whereas the rest of numbers of preceding backgrounds yielded a valid RP, but with lower amplitude.

However, it is our opinion that the RP obtained when only one background precedes the word is also contaminated, and this situation yields the apparent RP enhancement. By considering Fig. 5 it can be observed that RP to a word preceded by just one background stimulus does not resolve completely after the RP period, in contrast to the rest of the situations. This may indicate the presence of a slow negativity presumably overlapping the RP time window, though lasting some time longer. This slow negativity could be an activity linked to the word presented just 500 ms earlier, and indeed it appears plausible that ERP modulations to a word do occur by this time, that is, approximately 700 ms after that word, especially when words are embedded in sentences (e.g. Osterhout and Holcomb, 1995; Kutas, 1997; Friederici, 1999). It must also be considered that electrophysiological responses to background stimuli as a function of the number of preceding backgrounds (Fig. 5, right) also displayed slightly larger negative values for the RP period when only one background stimulus preceded a background, thus reinforcing our interpretations.

The rest of the situations, that is, when two or more background stimuli precede each word, yielded highly similar results. This would be an interesting result that further reinforces the insensitivity of RP to probability effects. Previous studies (e.g. Johnson and Donchin, 1982) have shown that it would be not so much the a priori or overall probability that matters and therefore affects certain ERP components such as the P300, but rather subjective expectancies. These expectancies depend not only on overall probabilities, but also to a large extent on local frequencies and local conditional probabilities. Subjective expectancies would radically differ as a function of the number of background stimuli preceding each word. Hence, when two background stimuli precede a word, the subjective probability for a word to appear would be approximately 12.5%, much less than the a priori 25% (as the mean number of background between words was 4 to 5). However, when eight background stimuli precede a word, the subjective must be 100%. However, RPs to words preceded by either 2, 4, 6, or 8 backgrounds were virtually identical.

Overall, these results further reinforce the insensitivity of RP to stimulus probability and indicate that a minimum number of two backgrounds appears advisable to attain a clean RP component. Additionally, if one wishes to randomize the number of interspersed background stimuli (a preferable procedure, as explained in Section 1), it appears evident that the number could vary between 2 and 8 without affecting at all the quality of the results.

3.3.2. Effects of SOA

As has been seen in Experiment 3, increasing the SOA from the standard 250 ms to 500 or 1000 ms restricts the visibility of a plain RP. With long SOAs this component appears masked by the presence of a strong P200 component. The activity reflected by RP should also certainly be present at longer SOAs, as RP presumably reflects language-related processes (e.g. Martín-Loeches et al., 1999, 2001b). However this activity would not be clearly manifest, as it would be sheltered, distorted or confused by the presence of a salient P200 component. It could therefore be discarded that RP were an artefact of certain (short) SOAs, which in our opinion is in any case highly implausible. In fact, the absence of the processes reflected by RP at longer SOAs would rather be the artefact, as 250 ms is a most natural SOA during reading (e.g. Perfetti, 1999)

The fronto-central P200 component is a fluctuation that appears to visual stimuli and seems sensitive to the identification of visual features, actually being considered a pre-lexical component (e.g. Brown et al., 1999), in contrast to RP (Martín-Loeches et al., 1999, 2001a,b). Its amplitude increase with longer SOAs would therefore not be surprising, and indeed the reduction of perceptive-related electrophysiological responses using a rapid rate of image presentation is one of the aims of using the RSS with an SOA of 250 ms (Rudell, 1992)

It must be discarded that the RP observed for an SOA of 250 with the average reference is a counterpart of the fronto-central P200, subsequent to the reference procedures. This possibility, indeed, appears implausible when one considers the peak latency of the two components, which differs by approximately 50 ms, and the fact that with such an SOA RP at PO7 displays larger amplitude values than the fronto-central P200.

In conclusion, the use of an SOA of 250 ms indeed seems advisable for better observing the RP, at least when compared to longer SOAs.

4. General discussion

One of the main findings of the present study is that RP can be obtained under normal conditions of language stimulation, that is, without the presence of background stimuli interspersed between words. However, the presence of background stimuli enhances RP amplitude—without affecting its topography—presumably by removing possible contamination phenomena due to electrophysiological fluctuations linked to previous word stimuli.

Another finding is that the minimum number of background stimuli between words should be two, as the presence of only one background does not guarantee the procurement of an RP free of influences by the processing of previous words. Given this state of affairs, it is clear that the design for best observing RP amplitude requires the presence of at least double the number of background stimuli than words, resulting in the standard situation in which the probability of words is always lower than that for non-words or background stimuli. However, one of the other main findings of the present study is that probability is not a variable affecting RP.

It can also be concluded from the present study that a rapid rate of stimulus presentation is preferable: RP failed to be properly seen when the SOA was either 500 or 1000 ms, whereas an optimal rate of presentation would be the standard 250 ms SOA.

Accordingly, the standard RSS paradigm is reinforced by the present experiments, its validity for exploring RP to words within sentences being established here. Hence, the confluence of certain manipulations, that is, the presence of at least two background stimuli preceding each word, an SOA of 250 ms, and the use of an average-reference method (as reported in Martín-Loeches et al., 2001a) would guarantee a remarkable RP. Even so, it seems clear from this study that not all the mentioned manipulations are required simultaneously

Thus, if RP is a potentially relevant component in the study of semantic manipulations (e.g. Hinojosa et al., 2001a; Martín-Loeches et al., 2001a,b), the remaining question that deserves consideration is: why is RP not reported in other studies where semantic manipulations are taking place, apart from the studies by Rudell and collaborators and Martín-Loeches and collaborators? In our view, the answer to this question can be approached by considering that this state of affairs is rather the result of a confluence of several circumstances.

First, we have shown here that RP can be obtained with a standard RSV paradigm (Condition 2 in Experiment 1), but in such a paradigm (i.e. in the absence of background stimuli) only the use of an average reference would give a noticeable RP, whereas other references would largely miss this component (see Fig. 8). In this regard, the RSV presentation paradigm is widely used in psycholinguistics, but its use in electrophysiological studies has been somewhat scarce. For instance, Kutas (1987) employed a rapid rate of word presentation (10 Hz), but used linked mastoids as reference, whereas Hagoort and Brown (2000) also used a RSV presentation but employed a left mastoid reference, which would aggravate the situation given the left-lateralization of RP.

In addition, not only is RP better seen in parieto-occipital leads, but its distribution is indeed limited to that region, its amplitude largely decaying as we move from PO7 or PO8 (see, for instance, Martín-Loeches et al., 2001a). Curiously, these electrodes are quite scarcely used in ERP research, where the mean number of electrodes used is not usually larger than 20, and neither PO7 nor PO8 have been included. Also, as has been proved here, RP is best seen with a rapid rate of stimulus presentation (SOA 250 ms), but this rate of presentation is not usual in electrophysiological studies. Rather, an SOA of 500 ms or longer is a more standard procedure in studies where experimental manipulations could relate to the processes presumably reflected by RP (e.g. Kutas, 1997).

Finally, it can be commented that another factor possibly contributing to the neglect of RP in psycholinguistic ERP literature is the particular interest of the authors in processes and/or components other than RP, so that they concentrate their attention on other features, disregarding an analysis of fluctuations in the time range and location of RP. For instance, Rolke et al. (2001), who presented words at 12 Hz using linked earlobes as reference, found what might be an RP in both occipital electrodes (e.g. Fig. 4 in that study), but made no mention of it.

Consequently, this study reveals that the RSS paradigm permits better study of RP to words embedded in sentences by simply improving the visibility of what could nevertheless be obtained with other, more conventional stimulation procedures. Even so, the use of the RSS paradigm may entail the limitation that it is not a natural or normal reading situation. In this regard, it may involve additional operations, such as assessing every incoming stimulus on whether it is a word or not, or ignoring the non-linguistic stimuli. However, the improved visibility of RP amplitude occurs without affecting RP topography. Moreover, some of these variables would differ as a function of the number of background stimuli preceding each word, whereas RPs to words preceded by any number of backgrounds were in fact virtually identical. It can therefore be assumed that the use of interspersed background stimuli does not introduce unwanted variables or processes affecting RP, but merely clears up overlapping components. In contrast to the case of other ERP components (such as P300), therefore, the cognitive processes reflected by RP do not appear to be affected by the variables manipulated in this study. It is simply the visibility of this component that would be affected.

Accordingly, and in our opinion, with the RSS paradigm the visibility of RP would be improved without affecting its nature, making it a low-risk—even though seemingly unnatural—stimulation procedure that would permit the detection of subtle but real effects of variable manipulations that might otherwise be neglected. Nevertheless, if one wishes to avoid the possible risks of such a procedure, what this study also reveals is that RP can be obtained without the need for any interspersed non-linguistic material.

Acknowledgments

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