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ERP components reflecting stimulus identification: contrasting the recognition potential and the early repetition effect (N250r)

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Abstract

The recognition potential component (RP) in the event-related brain potential (ERP) appears during rapid stream stimulation and has been related to the activation of word form or word meaning. The early repetition effect (ERE/N250r) is observed in repetition priming designs and has been linked to the access to stored representations of the structure of familiar faces and names. Because of the apparent similarities in latency, topography and theoretical interpretation we compared the RP and ERE/N250r within the same rapid stream stimulation design and for the same type of stimulus material: names and faces of famous persons and names and pictures of common objects. Contrasting with RP, the ERE/N250r occurred later and differed in both scalp topography and amplitude patterns across stimulus conditions. Therefore, the ERE/N250r seems to reflect a separate and content-specific stage of information processing, following the RP, which appears to reflect domain-general processes of structural analyses.

Keywords: Language; Face recognition; Recognition potential; Early repetition effect; N250r; Semantic processing; Structural processing

1. Introduction

Recently, several components in the event-related brain potential (ERP) have been suggested to indicate the identification of a visual stimulus. In the focus of the present paper are two ERP components, the recognition potential (RP) and the early repetition effect (ERE) or N250r. Both components have been linked to the access of presemantic representations of words or faces, respectively, and appear to have similar peak latencies and scalp topographies. However, direct comparisons within the same experiment have never been made. Therefore, we measured both components within the same experimental design, with the same type of stimuli and in the same participants. As will be shown, the two components differ in crucial respects.

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The comparison of both components will be made here in the frame of some influential models for picture and written name recognition. According to these, when an observer sees a picture of either type or a written name, a visual analysis is performed, a kind of analysis that is common to any type of visual stimulus, resulting in pictorial codes (Marr, 1982). Subsequently, and mainly based on previous knowledge, structural representations are extracted, capturing the typical aspects of the object or face (for instance, physiognomy in the case of a face) independent of surface or situational properties such as lighting or viewpoint, or the extraction of whole words in the case of names (a word-form analysis), which again would be independent of situational properties such as the type or size of the font used. In the next step, the structural representations would be compared with stored representations of objects, faces or names, such as the so-called face recognition units (Bruce and Young, 1986) or name recognition units (Valentine et al., 1991). Thereafter, semantic information is accessed, which would be common to any domain or modality.

The RP is best seen if a rapid stream stimulation paradigm is used, a procedure in which background stimuli (i.e., nonsense stimuli superficially resembling words or pictures) are presented at a high rate and a word or a picture occasionally substitutes a background (Rudell, 1992; Hinojosa et al., 2001). RP usually peaks around 250 ms when subjects view recognizable images (Rudell, 1991; Martín-Loeches et al., 1999; Hinojosa et al., 2000) and is strongly related to conscious awareness of the stimuli, selective attention being an important factor for evoking it (Rudell and Hua, 1996). RP seems to index at least part of 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, such as the semantic category of the stimuli (Martín-Loeches et al., 2001a,b). However, a presemantic, more structural level of analysis has also been conceived as the process reflected by this component (Rudell et al., 2000; Martín-Loeches et al., 2004). Recently, the RP has been shown to be affected by context effects (Martín-Loeches et al., 2004). 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). The topography of RP appears relatively homogeneous across studies and materials, displaying a bilateral temporooccipital negative maximum with a slight left lateralization for verbal material (Hinojosa et al., 2001; Martín-Loeches et al., 2001b).

The ERE/250R was first observed in a prime-target paradigm with faces (Begleiter et al., 1995; Schweinberger et al., 1995). Schweinberger et al. (1995) presented portraits of celebrities and unfamiliar persons. Different kinds of primes preceded the target by 1.8 s. If a celebrity's portrait had been repeated (i.e., primed), ERPs around 250 ms after target onset were more positive at frontal and more negative at temporal electrodes as compared to when it was unprimed, a finding that is now well replicated (e.g., Herzmann et al., in press; Itier and Taylor, 2002). This priming-related diminution of the ERP was called early repetition effect (ERE) in order to distinguish it from a subsequent late repetition effect that has been related to the N400 component; in more recent articles, the ERE is also referred to as N250r (Schweinberger et al., 2002; Pickering and Schweinberger, 2003). When semantically associated persons were used as primes and targets, there was an N400 again but no ERE/250r. Whereas there was also a (smaller) ERE/250r for unfamiliar faces in the study of Schweinberger et al. (1995), the ERE/250r appeared only to familiar faces when a continuous recognition paradigm was used with other stimuli intervening between repetitions (Pfütze et al., 2002). Importantly, Pfütze et al. (2002) and Pickering and Schweinberger (2003) observed an ERE/250r also for names of celebrities but with a different scalp distribution, indicating domain specificity. Because of the sensitivity of the ERE/250r to stimulus familiarity (for both faces and names) and its domain-specific scalp topography (faces being more right-lateralized, names more left-lateralized), Pfütze et al. (2002) suggested that the ERE/250r might reflect the access to stored knowledge about the structure of faces and names, respectively. In contrast, the late repetition effect or N400 was consistent with access to other kinds of knowledge about the person. Within the context of cognitive theories about face and name recognition, the ERE/250r would therefore reflect the access to face and name recognition units, respectively (Bruce and Young, 1986; Valentine et al., 1995). This interpretation was strengthened by more recent findings by Schweinberger et al. (2002) that the N250r (i.e., ERE/250r) also appears when different portraits of the same person are presented as prime and target.

From the preceding paragraphs, it should have become clear that the RP and ERE/250r share several characteristics and are interpreted in a similar way. Overall, both components display peak latencies around 250 ms (Rudell, 1992; Schweinberger et al., 1995) and topographic patterns consisting of a temporooccipital negativity together with a frontal positivity (Schweinberger et al., 1995, 2002; Martín-Loeches et al., 2001a). Both components are interpreted as reflecting the access to stored knowledge, rather than primary perceptual operations, and the type of stored knowledge seems to be domain-specific at least in some sense. Thus, RP amplitude is sensitive to the semantic category of the stimuli, being larger for concrete/imageable than for abstract/nonimageable words (Martín-Loeches et al., 2001b). In addition, ERE/250r has usually been reported in the frame of face identification and presumably reflects the activity of face recognition units, although a domain-specific lateralization of ERE/250r topography has been reported for faces as compared to written names, the former being lateralized to the right, the latter to the left (Pfütze et al., 2002). Different lateralization patterns for names and pictures have also been reported for RP, yielding a left lateralization for names and a right one for pictures (Hinojosa et al., 2000).

According to these common features, the RP and ERE/250r might indeed reflect the same neuronal and cognitive process. However, there are also subtle but perhaps crucial differences between both components that might weaken this assertion. In this regard, although similar topographies can be assumed, small differences can also be observed. For instance, whereas RP has been consistently reported as displaying a temporooccipital negative maximum, ERE/250r can display different topographies (Pfütze et al., 2002). More importantly, it has to be pointed out that all the possible comparisons between the components are by necessity superficial because as yet there have been no studies that measured both components under the same conditions. In particular, the ERE/250r has only been investigated for names and faces of people and the RP has only been assessed for names and pictures of common objects. Therefore, it was the primary aim of the present study to record the ERE/250r and RP with the same stimulus material and in the same subjects. This would allow a direct comparison of the components in terms of amplitude, latency and topography. In order to do so, we modified the rapid stream stimulation procedure by including stimulus repetitions, hopefully allowing to record both the RP and the ERE/250r.

In particular, we aimed at assessing the domain specificity of both components across four types of stimuli, namely portraits and names of famous persons and pictures and names of common objects. If ERE/250r and RP reflect the same cognitive process we should observe similar response patterns across the four stimulus classes. As a second objective, the choice of stimuli extents the range of conditions studied for both the RP and the ERE/250r. As outlined above, the RP has never been studied for persons and the ERE/250r has not yet been investigated for common objects.

2. Methods

2.1. Subjects

Thirty native Spanish-speaking students (22 females, mean age 19.9 years, range 18–27) were paid for their participation in the experiment. They were right-handed, with average handedness scores of +83, ranging from +53 to +100 according to the Edinburgh Handedness Inventory (Oldfield, 1971). All participants had normal or corrected-to-normal vision.

2.2. Stimuli

Experimental stimuli were common objects, available as names (objects names, ON) and as pictures (objects pictures, OP) and famous persons, available as names (persons names, PN) and as portraits (persons pictures, PP). Portrait photographs of famous persons were in black-and-white, and had been selected on the basis of ratings made by 10 persons not taking part in the experiment proper. Raters were given a list of 200 names of people from fields such as politics, sports, arts, cinema and television. This list was constructed by including only famous people that could be recognized by a single name (usually the surname, as in “Blair”, but this was not always the case, as in

"Sting"). This criterion was applied in order to resemble the list of object names, composed by single names. Each celebrity was rated on a three-point scale for the familiarity with that name, ranging from 0 (unfamiliar) to 2 (very familiar) and for the confidence in recognizing that person's face, ranging from 0 (would not recognize) to 2 (would certainly recognize). The 81 celebrities with the highest mean ratings were selected for the experiment. Mean familiarity rating for all these persons was above 1.5 (mean 1.92). Object pictures were black-and-white photographs of common objects, such as a chair or a spoon, and were selected from a list of 200 items following exactly the same procedure used for the celebrities. The 81 objects with the highest mean familiarity ratings (always >1.5; mean 1.89) were used in the experiment.

Names of the same persons and objects that were used as pictures were shown in light gray print and capitalized letters on a black background at the center of the monitor. Names of persons were composed by M=6.67 letters (range 4–11) and names of objects had a mean length of 6.72 letters (rang 3–11). All stimuli were presented on a NEC computer MultiSync monitor, controlled by the Gentask module of the STIM package (NeuroScan). Participant's eyes were 65 cm away from the screen. Overall, stimulus width by height ranged between 2.1–9 by 2–4 cm, respectively (portraits: 2.3–3.3 by 3.5–4, person names: 2.4–9 by 2, object pictures: 3.5–4 by 3.7–4, and object names: 2.1–6 by 2 cm).

Experimental stimuli were embedded into a stream of background stimuli, as will be detailed in the Procedure section. A total of 240 background stimuli was made by cutting some exemplars of ON, OP, PN and PP stimuli into 30 rectangles each; these rectangles were randomly mixed and rearranged in order to attain background stimuli composed in equal parts of elements of all four types of experimental stimuli. Width and height of the background stimuli was 4 by 3.5–4 cm, respectively.

As mentioned, there was a total of 81 common objects and 81 famous persons. One common object and one famous person were used as targets (see below). The rest of the 80 stimuli per type of content (objects/persons) were used as follows; for half the participants, the first 40 common objects were presented as pictures (OP) and the other 40 common objects as names (ON); the same procedure was followed for the 80 celebrities. The presentation of persons and objects as names and pictures was reversed in the remaining participants. In this manner, each object/person was presented in only one domain for each participant while balancing domain of presentation across participants.

2.3. Procedure

Stimuli were presented in blocks, consisting in 10 randomly selected exemplars of each of the four stimulus types (ON, OP, PN, PP). The rapid stream stimulation paradigm was implemented by inserting 2–4 background stimuli after each experimental stimulus. Each block started with six or seven backgrounds, followed by the first experimental stimulus, and ended with six backgrounds. To attain the ERE/250r, each experimental stimulus was repeated once at equiprobable lags of 1, 2, or three experimental stimuli. Stimulus onset asynchrony (SOA) was 250 ms, and there was no interstimulus interval. Fig. 1 exemplifies the stimulation procedure. A total of four experimental blocks was presented to each participant.

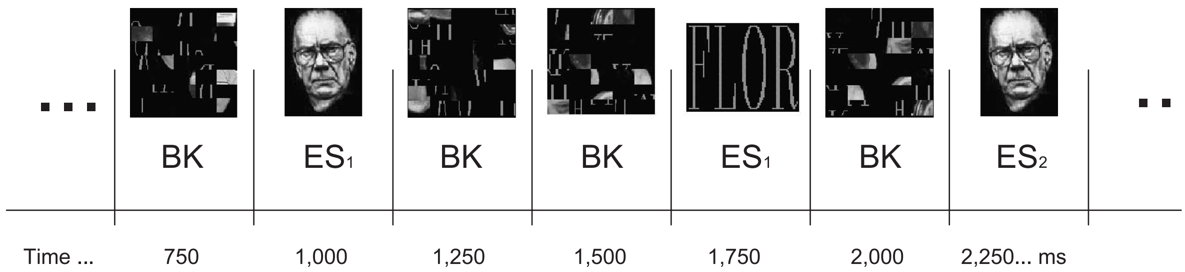

Fig. 1. Sample of the stimulation procedure. 'BK' refers to background stimuli, whereas '$ES_{(n)}$' refers to experimental stimuli (and order of presentation).

As mentioned, one common object and one famous person were defined as targets, which could appear either as name or picture; in each block each of these four possible target stimuli appeared once at randomly determined positions. Participants were instructed to indicate the appearance of any target stimulus by pressing a button with the right hand.

A practice block preceded the experiment proper, containing other stimuli than those in the experimental blocks. Each block was started with a button press by the participant, initiating a message on the screen with the invitation to blink now so as to minimize blinking during stimulus presentation, which was started by a second button press.

2.4. Electrophysiological recordings

Scalp voltages were recorded from a total of 60 tin electrodes; 58 electrodes 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), except for PO1 and PO2, which are located halfway between POz and PO3 and between POz and PO4, respectively. Additional electrodes were placed at the mastoids (M1 and M2). All EEG recordings were initially referenced to M2. The electrooculogram (EOG) was recorded from below vs. above the left eye (vertical EOG) and the left vs. right lateral orbital rim (horizontal EOG). Electrode impedances were kept below 3 kΩ. The signals were recorded continuously with a band pass from DC to 100 Hz and a sampling rate of 250 Hz. The data were filtered offline using a 0.3–50 Hz band pass.

2.5. Data analysis

EEG epochs were extracted between 200 ms before and 824 ms after the onset of each experimental stimulus. Artifacts were automatically rejected by eliminating epochs with amplifier saturation or EEG activity in any channel exceeding ±65 μV. Offline correction of smaller eye movement and blink artifacts was made, using the method described by Semlitsch et al. (1986) and all epochs were calculated to average reference (Lehmann, 1987), reobtaining the activity at M2. After removing target stimuli, average ERPs were computed for each type of stimulus (ON, OP, PN, PP) and presentation order (first presentation, second presentation). The averages were aligned to a 200-ms prestimulus baseline.

Data analyses depended on the component in question. RP was analyzed in the ERPs to the first presentations and identified as the most negative peak within the interval between 160 and 417 ms after stimulus onset, centered on the expected peak latency of the RP (Rudell and Hua, 1996; Hinojosa et al., 2001). A single window centered at the peak of the RP +28 ms in each condition was used for mean amplitude measurement. A repeated-measures analysis of variance (ANOVAs) was performed including the factors stimulus content (person vs. common object), stimulus domain (picture vs. name), and electrode site (60 levels). RP latency was measured at PO7 (according to Hinojosa et al., 2001) and analyzed with a similar ANOVA, but without factor electrode. ERE were analyzed in the difference waves between 2nd and 1st presentation by measuring the mean amplitudes for adjacent 50-ms segments starting at 50 ms and finishing 500 ms after stimulus onset. The ANOVAs included four factors: stimulus content (person, common object), stimulus domain (picture, name), presentation (first, second), and electrode (60 levels). Subsequently, results from these ANOVAs determined the presence or absence of ERE/250r for a given condition at a given moment, thereby defining the specific 50-ms wide windows to be used for further amplitude comparisons. These windows were centered on the largest observed amplitude value for each included condition. The Geisser–Greenhouse correction was applied to all ANOVAs. The average reference sets the mean activity across electrodes for a given condition to zero, which implies that the effects to be considered will be only those in interaction with factor electrode. Finally, post hoc analyses on amplitude with the Bonferroni correction were performed but, for the sake of simplicity, only in the electrode showing the highest amplitude for each particular ERP component.

Profile analyses (McCarthy and Wood, 1985) were performed in order to assess differences in scalp topographies independent of overall ERP amplitude. For the time windows of interest (depending on each component and condition), mean amplitudes were scaled for each subject across all electrodes, with the average distance from the mean, calculated from the grand mean ERPs, as denominator. Significant differences in ANOVAs with these scaled data, where possible effects of source strength are eliminated, indicate different scalp distributions (Rugg and Coles, 1995). ANOVAs were therefore performed on these scaled data with the aim of comparing RP and ERE/250r topographies, both within and between components. Again, the effects to be considered will be only those in interaction with factor electrode.

Behavioral results (reaction times, RTs) were also analyzed by means of an ANOVA including the factors content (person, common object), domain (picture, name) and presentation (first, second).

3. Results

Behavioral data revealed a mean of 98.4% correct target detections (1.5% omissions, 0.16% anticipations/delays (300<RT<900 ms, based on suggestions by Rudell and Hua, 1996); the mean occurrence of false alarms was 1.53%. Together, these data show that subjects were performing correctly and attending the task, as requested. Mean reaction times for targets (first vs. second presentation) were as follows [*M* (S.D.)]: Objects names: 505.9 (84.3) vs. 435.0 (71.1) ms, person names: 533.1 (93.9) vs. 436.5 (91.7) ms, object pictures: 528.3 (74.8) vs. 463.1 (102.6) ms, and person pictures: 506.4 (85.1) vs. 464.1 (94.9) ms. There was a significant main effect of presentation ($F_{1,29}$=19.8; p=0.0001), reflecting that RTs to repeated stimuli were about 70 ms faster than to initial presentations. This advantage depended on the type of stimulus, as reflected in a significant interaction of presentation by content by domain ($F_{1,29}$=6.3; P<0.05). A significant main effect of content by domain interaction ($F_{1,29}$=4.4; P<0.05) was also found.

Data of the present study are summarized in Fig. 2. At the temporooccipital electrodes (e.g., PO7 and PO8) the Recognition Potential (RP, obtained form the 1st presentations) is clearly visible. It peaked at different latencies, depending on the type of experimental stimulus. This was at about 210 ms after stimulus onset for both kinds of names [*M* (S.D.)]=210.1 (27.2) for objects names, 208.2 (19.7) for persons names, at 193.8 (31.9) ms for pictures of persons, and 236.6 (44.2) ms for common object pictures, although in the latter case the peak of the RP was rather broad. ANOVA revealed a main effect of content ($F_{1,29}$=28.7; P=0.0001), a significant content by domain interaction ($F_{1,29}$=15.6; P=0.0001), but no main effect of domain alone ($F_{1,29}$=0.8; P>0.1). Bonferroni corrected post hoc comparisons indicated that the latencies in the OP condition were longer than all others, which did not significantly differ from each other.

Since ANOVA results revealed significantly different latencies for the types of stimuli, specific time windows were applied for amplitude measurements. An ANOVA on these amplitudes revealed significant main effects of content ($F_{59,1711}$=7.7; P=0.0001) and of domain ($F_{59,1711}$=41.3; P=0.0001), and an interaction of these variables ($F_{59,1711}$=3.6; P=0.01). Pairwise amplitude comparisons at both the PO7 and PO8 electrode revealed the following ordering of conditions: OP<PP<ON=PN.

The topography of this component can be seen in Fig. 2. It was rather symmetric for both types of names, but appeared to be somewhat right-lateralized for the pictures, and peaked at PO7 and PO8 within each hemisphere, respectively. However, a profile analysis revealed no significant topographic differences (F's≤1.5).

ERE/250r difference curves, obtained by subtracting the second and the first presentations, are also presented in Fig. 2. At the temporooccipital electrodes, and with a certain left lateralization, a small ERE/250r can be observed for both pictures of persons and person names. Although peak definition cannot be made as precisely for ERE/250r as for RP, the peak was at about 280 ms after stimulus onset for PP, whereas for PN there appeared to be two maxima around 150 and 300 ms. Object pictures showed an ERE/250r at about 240 ms. However, no ERE/250r can be seen for object names. For this reason, no ANOVA was performed to calculate latency differences in ERE/250r, and an analysis based on consecutive time windows was preferred for initial amplitude analyses.

ERE/250r amplitude was first analyzed in unsubtracted waveforms by considering only effects includ-

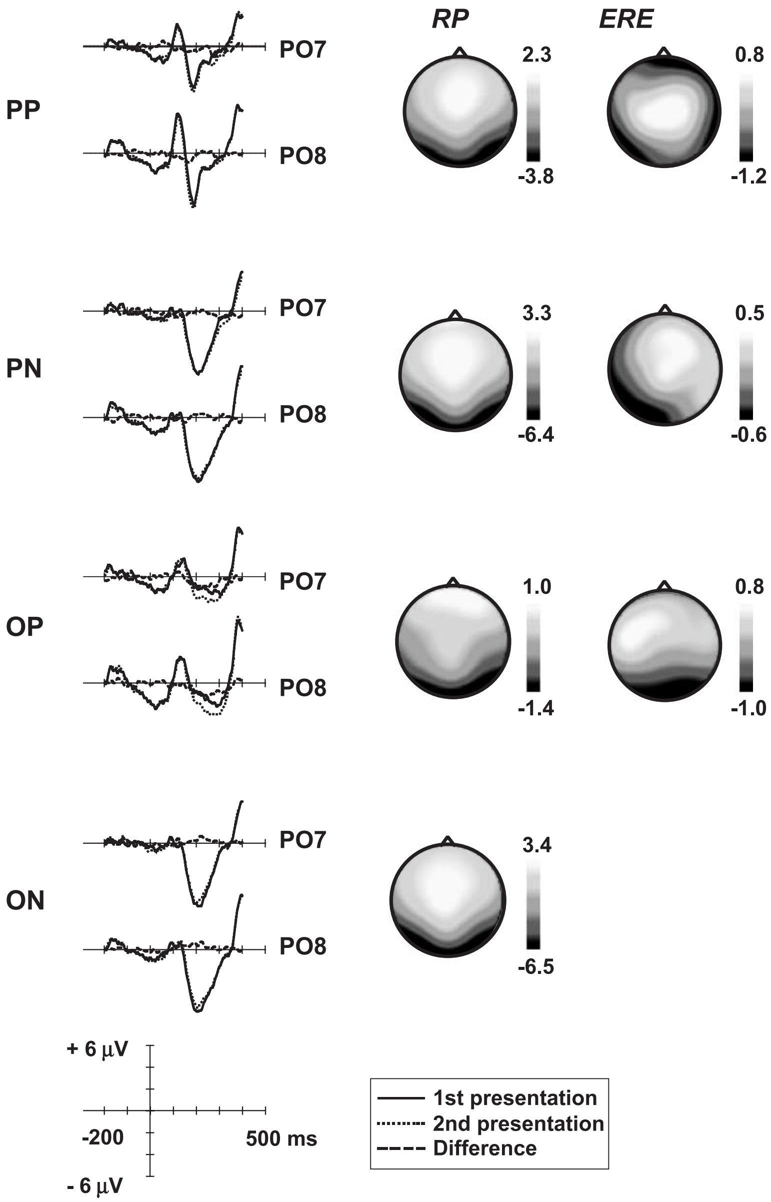

Fig. 2. Summary of main results of the present study. PP refers to people pictures (faces); PN to people names; OP to object picture, and ON to object names. Left: ERP waves in parietooccipital leads for the four types of stimuli for the first and the second presentations, as much as the difference between both presentations. RPs were measured in the first presentations, whereas ERE/250r were obtained form the difference waves. Right: maps for each component for the different stimuli. Note that individual scales are provided for each map, and that these are based on the particular maxima and minima, therefore enhancing the visibility of the topographies. No ERE could be observed in the difference waves for object names (ON); accordingly, no maps are reported.

ing factor presentation (and, as mentioned in the Methods section, electrode). Results are summarized in Table 1. Significant main effects of presentation were obtained for the three time segments from 250 to 400 ms. Presentation interacted with domain in the 200–250 ms window and with content between 250 and 350 ms. These results indicate that the first peak of ERE/250r in the PN condition is not significant.

Table 1
ERE results in consecutive time windows

	50–100 ms	100–150 ms	150–200 ms	200–250 ms	250–300 ms	300–350 ms	350–400 ms	400–450 ms	450–500 ms
Presentation	–	–	–	–	**(5.02)	*(3.2)	*(2.5)	–	–
Present×domain	–	–	–	*(2.6)	–	–	–	–	–
Present×content	–	–	–	–	*(3.6)	*(2.6)	–	–	–
Present×domain×content	–	–	–	–	–	–	–	–	–

Overall ANOVA.
($F_{59,1711}$ in parentheses).
* $p<0.05$.
** $p<0.001$.

Post hoc analyses were performed at the electrodes of interest (PO7, PO8, O1 and O2), for those windows where overall ANOVA had yielded significances. Results are summarized in Table 2. They confirm the absence of ERE/250r for object names. Post hoc analyses also showed that for object pictures ERE/250r was actually significant in the right but not in the left temporooccipital electrodes.

Table 2
ERE/250r post hoc analyses between first and second presentations at locations PO7, PO8, O1, and O2

	200–250 ms	250–300 ms	300–350 ms	350–400 ms
Object names				
PO7	–	–	–	–
PO8	–	–	–	–
O1	–	–	–	–
O2	–	–	–	–
Object pictures				
PO7	–	–	–	–
PO8	*(3.1)	*(2.9)	–	–
O1	–	–	–	–
O2	*(2.8)	–	–	–
Persons names				
PO7	–	–	*(2.7)	*(2.9)
PO8	–	–	–	–
O1	–	*(2.6)	*(2.6)	*(3.1)
O2	–	–	–	–
Persons pictures				
PO7	–	*(2.6)	–	–
PO8	–	–	–	–
O1	–	–	–	–
O2	–	–	–	–

Time segments from 200 to 400 ms.
(t_{29} in parentheses).
* $p<0.05$ after Bonferroni correction.

These results determined which conditions yielded an ERE/250r and when this occurred. Thereafter, specific 50-ms windows were defined for ERE/250r amplitude measurements and calculations on subtracted data (1st minus 2nd presentations). These windows were 250–300 ms for PP, 350–400 for PN, and 200–250 ms for OP, ON yielding no observable ERE/250r. An ANOVA was then performed with the factor condition (PP, PN and OP, omitting ON), and electrode (60 levels). This resulted in a significant condition effect ($F_{118,3422}$=2.9; $P<0.02$), supporting the amplitude differences displayed in Fig. 2 (actually, negativities with the following order: PN<OP<PP).

The ERE/250r topography can be seen in Fig. 2. This appeared rather different for each condition. A profile analysis based on the specific 50-ms windows defined above revealed a trend for significance for the condition factor ($F_{118,3422}$=2.2; $P<0.1$), supporting to some extent this differing topography between conditions. These scaled data for the ERE/250r were used in combination with those for the RP in order to perform a subsequent profile analysis comparing both components. The ANOVA on these data included the factors condition (PP, PN and OP), component (two levels: RP, ERE/250r), and electrode (60 levels). The results yielded a clear component effect ($F_{59,1711}$=6.1; $P<0.0001$), a trend in the component by condition interaction ($F_{118,3422}$=2.2; $P<0.1$), and no main effect of condition ($F_{118,3422}$=1.4; $P>0.1$).

4. Discussion

The main aim of this study was assessing to what extent the recognition potential (RP) and the early repetition effects (ERE/250r) reflect similar neuronal and cognitive processes by comparing these components across a range of stimuli within the same paradigm and participants. This also provided the opportunity to broaden the range of conditions studied for each component. Although this extension was our second goal, it is useful to first discuss the findings across the different conditions for each component before making the comparison across components.

Previously, the RP has mostly been studied with words. The present findings for names of objects are largely consistent with these previous findings in terms of RP latency, amplitude and topography. As compared to object name RP, the response to object pictures was much smaller, later, and more restricted in the frontal positivity. In some sense these findings are similar to those by Hinojosa et al. (2000). Their RP to line drawings of objects was also smaller and frontally more restricted than the RP to words. Both in the present and Hinojosa's et al. (2000) study, profile analyses revealed no substantial topographic differences between the RPs to pictures (line drawings) and words, however. But, indeed, this might be a question of statistical power, and the fact that some difference can be perceived in two studies could support this assertion.

Whatever the cause, in the study by Hinojosa et al. (2000), RP to pictures peaked earlier than RP to words, whereas the opposite was found here. A suitable explanation for the latency delay observed here for RP to object pictures is that the backgrounds used might bear a closer resemblance to the object pictures than to the other types of stimuli. Whereas there are canonical overall shapes for all kinds of names and all faces, allowing a ready distinction from the variable background stimuli, objects are more heterogeneous, possibly making them more difficult to distinguish. This explanation, however, contrasts with behavioral data, as RT for recognizing person names was even longer than for object pictures. The explanation might be valid only if the content dimension (objects, either as names or as pictures) is considered. Heightened visual heterogeneity could also explain the smaller amplitude for object pictures RP, as the electrical modulation could have been smeared by a larger variation in latency. Indeed, as mentioned in the Results section, RP latency variation appeared larger for RP to object pictures than for any other type of stimulus, although detailed analysis of the data also revealed that all subjects displayed smaller RP amplitudes to object pictures.

The RP to names of people is quite similar to the RP to names of objects in terms of latency, amplitude, and scalp distribution. Thus, it appears that RP cannot distinguish these types of stimuli. On the other hand, the RP to faces appeared earlier (although non-significantly so) than to any of the other stimulus types; it was somewhat smaller in amplitude but quite similar in topography as compared to names. Nevertheless, RP to faces appeared certainly conspicuous, probably indicating that the processes reflected by that component resolved much earlier than in the other conditions.

Hitherto, the ERE/250r has been studied in prime-target and continuous recognition paradigms, which are quite different from the rapid stimulation procedure employed here. Nevertheless, the ERE/250r for faces was broadly consistent with ERE/250r observed in previous studies in terms of latency, amplitude, and scalp distribution. Looking at Fig. 2, the ERE/250r to person names was more left-sided than that to faces, which corresponds to findings of Pfütze et al. (2002). Pickering and Schweinberger (2003) also reported a left-lateralized ERE/250r effect for person names. In addition, the longer latency and the smaller amplitude for present name— as compared to face—ERE/250r corresponds to results from the study of Pfütze et al. (2002). Interestingly, where present, the topography of the ERE/250r appeared different across conditions, which is supported by a statistical trend in the profile analyses. Although in statistical terms it was a trend, this difference appears as a robust one since, as mentioned, it replicates and extends previous findings.

In contrast to the other conditions, there was no significant ERE/250r for object names. It cannot be discarded that this absence of ERE/250r for object names might be partially a consequence of an overall ERE/250r amplitude reduction due to the experimental conditions used in the present study. Indeed, the use of intervening items between repetitions may have attenuated this component (compare results by Pfütze et al., 2002 with those by Schweinberger et al., 1995). Although, this differential response of the ERE/250r to object names as compared to the other conditions, in which the experimental conditions were identical, further reinforces the specificity of this component.

Together, we were able to elicit an ERE/250r in the modified rapid stream stimulation procedure, as indicated by the replication of ERE/250r findings for the person-related stimulus conditions. Therefore, it is possible to address the major issue of the present study, the comparison of both RP and ERE/250r across the different conditions.

As far as latencies are concerned, the RP to object pictures was quite broad, making it risky to determine a reliable peak for this condition. On the other hand, object names did not display a significant ERE/250r. Therefore, the comparison of component latencies has to be confined to the person name and person picture conditions with discernible peaks. In these conditions, RP appeared about 100 ms earlier than ERE/250r when recognizing names or pictures of persons. These differences would indicate that the processes reflected by RP functionally precede those reflected in ERE/250r.

In the present study, we compared the functional relationship for the two components by using four types of stimuli. Therefore, we can compare the pattern of component amplitudes across the different types of stimuli. A first and certainly striking difference in this regard is the abovementioned absence of an ERE/250r for names of objects, whereas RP amplitude to these stimuli was actually the largest one observed. In addition, the noticeable amplitude difference between RP to names and RP to person pictures, with the former being about two times larger than the latter, was reversed for the ERE/250r.

A third criterion for comparing RP and ERE/250r is topography. Overall and as expected, both components do not seem to display noticeably different topographies. Both components display posterior temporooccipital negativities and anterior positivities (with some variation for the ERE/250r to faces). But the existence of differences between components must also be mentioned, and profile analyses were unambiguous in this regard. Here, it could be noted that RP displayed a more homogeneous topography, with maxima always at temporooccipital electrodes (PO7, PO8), although trends for lateralizations could be observed for pictures. However, ERE/250r depicted a more heterogeneous distribution, since maxima appeared sometimes at temporooccipital electrodes but some other times at occipital leads (object pictures), and sometimes included frontal electrodes (person pictures).

Considering these differences, it appears that both RP and ERE/250r should not be identified as the same fluctuations but rather reflect different brain functions, and, therefore, different cognitive processes or stages of information processing. In this regard, the present results might help to better understand which stages or processes are reflected by these components.

Given that the RP and ERE/250r reflect different cognitive processes, how can these be described and differentiated? Regarding the RP, it must be said that, as mentioned, the processes reflected by this component appear to precede those reflected by ERE/250r, at least regarding the identification of pictures and names of persons. Although RP is sensitive to the semantic content of the information provided by a name (e.g., Martín-Loeches et al., 2001b), it appears that RP could be reflecting to a large extent some stage in the visual presemantic processing. At least as regards name processing, the most plausible candidates appear to be word-form identification processes. The finding that the RP to either names of persons and names of objects did not differ in this study, whereas they both differed when compared to other types of stimuli further reinforces this assumption. This would be in consonance with the conclusions recently outlined in Martín-Loeches et al. (2004), where it was proposed that RP might reflect lexical selection processes for the visual modality, an intermediate step in language processing in which form-based and content-based information are combined to select the appropriate word.

Obviously, word-form analysis seems a valid interpretation for the processes reflected by RP to names, but not for pictures. Regarding the RP to person pictures, it is our opinion that this could be identified with the N170 component reported as specifically sensitive to faces (Bentin et al., 1996) and presumably reflecting structural face encoding (Eimer, 1998; Eimer and McCarthy, 1999), which might occur within the fusiform or the occipitotemporal gyrus (e.g., Allison et al., 1994; Schweinberger et al., 2002). Its shape and its temporooccipital distribution in the current study support this assumption, whereas the latency delay might relate to the rapid stream stimulation procedures. In line with this, it appears also possible to relate our RP to words with a N170 component reported for words and presumably resembling the processes reflected by the face-specific N170 but for words (Bentin et al., 1999) that is, a structural analysis of the stimulus.

However, identifying RP with N170 might be problematic because of several reasons. First, even in absence of the rapid stream stimulation (Iglesias et al., 2004) the latency of the RP to words is still much later than the one for the previously reported N170 to words. Second, whereas N170 to words and letter strings are similar, this is not at all the case for RP, which is specifically sensitive to valid words (e.g., Martín-Loeches et al., 1999). Finally, N170 is similar in terms of latency and shape for either words, faces, and object pictures, the topography differing between these categories (e.g., Rossion et al., 2003), whereas, as the present study reveals, the opposite is true for the RP.

It remains relatively unclear to which specific process the RP to pictures of objects might relate. According to the interpretations given for the other types of stimuli, it appears reasonable to conceive it as reflecting some kind of structural processing for pictures of objects. In this regard, RP to pictures resembles the classical N200 component, a component sensitive to attentional demands during perceptual information processing (e.g., Coles and Rugg, 1995).

Early repetition effects (ERE/250r) have been shown to reflect later and, hence, presumably deeper stages of information processing. Perhaps the most noticeable finding in this regard is the striking difference between the results to names of persons and names of objects. These two types of stimulus are largely similar in the perceptual level, and both share the necessity to perform a word-from analysis. However, and at variance with the results for RP, which was fairly identical for either type of name, there was an ERE/250r for names of persons but no ERE/250r for names of objects. Accordingly, the identification of the type of content coupled to a given name has plainly taken place when developing an ERE/250r.

In addition, ERE/250r does not seem completely independent of perceptual processes or, at least, of access routes to the semantic information contained within a stimulus. This is suggested by findings such as the slight topographical differences between ERE/250r to names of persons and pictures of persons. “Persons” (the same persons, actually) is the same semantic information accessed by either pictures or names. Pfütze et al. (2002) also reported slight differences in topography between names of persons and pictures of persons. Even more prominent in this regard is the difference between object names and object pictures. Again, semantic information of objects is the same regardless of the modality or domain of stimulation, but both stimuli qualitatively differed in terms of ERE/250r (no ERE/250r for object names). Similar phenomena, however, can be accounted for other presumably modality independent components such as the N400, which has nevertheless been found to differ in topography when the visual and the auditory modality are compared (e.g., Gomes et al., 1997). Nevertheless, it is our opinion that ERE/N250r would most probably reflect the comparison of structural representations with stored representations of faces, objects or names.

It is worth to be mentioned that the topographies depicted by ERE/250r to objects pictures and ERE/250r to persons pictures were perceptibly different. Provided that ERE/250r would reflect content processing, as mentioned above, and considering that both types of stimuli share the pictorial domain, this finding might interestingly be related to differences within the memory store. That is, faces and objects might be stored at different places. This could relate to the general-particular knowledge dimension proposed for the organization of information within the long-term memory store (Martin and Chao, 2001). According to these proposals, general knowledge, as that contained in pictures of common objects, would be distributed within more posterior regions of the temporooccipital areas, whereas knowledge on particular entities, as would be the case for famous persons, would be distributed throughout more anterior regions. However, in the present experiment, the general-particular knowledge difference is confounded with a difference between processing persons and objects. It appears, therefore, pertinent to further disentangle these variables in future research.

In sum, RP and ERE/250r seem to reflect two different and consecutive information-processing stages. Whereas the former appears to relate to structural processes largely common to either content (persons of objects) or domain (pictures or words), ERE/250r might reflect subsequent processes in which content-specific information is relevant.

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