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The Many Facets of Repetition: A Cued-Recall and Event-Related Potential Analysis of Repeating Words in Same Versus Different Sentence Contexts

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Event-related potential (ERP) and cued-recall performance were used to investigate the influence of (a) context, (b) repeating a word's meaning to word repetition priming, and (c) repetition on the ERP difference related to memory (Dm). Sentences ended with either nonhomographs or homographs. For nonhomographs, either the sentence context, the final word, both, or neither were repeated. Homographs were repeated in their original context or in new sentences that biased the same or an alternative meaning. Large repetition effects were found for all words repeated in their original contexts; in contrast, changing contexts led to no repetition effects whether the meaning of the repeated words was preserved or not. These results favor an episodic contribution to word repetition priming and suggest a common process for Dm and repetition.

Whereas there is a consensus that *repetition priming*, defined as the facilitation in processing accorded a word on its second presentation, is a consequence of the trace left by a previous encounter with the word, the nature of the information constituting this trace is still a matter of intense debate between the proponents of an abstractionist and those of an episodic account. Abstractionist views are based in large part on the "logogen" model of word recognition developed by Morton (1969, 1979). When a word is presented, its corresponding lexical unit (i.e., logogen) is activated. If the logogen is still activated at the time of the word's second occurrence, the logogen's threshold is lowered, thereby facilitating the word's processing.[1] In Morton's (1979) words: "It is, then, a central part of the [logogen] concept, that any use of the logogen will give rise to subsequent facilitation of its use" (p. 260). In its strongest form, the abstractionist account predicts that repetition priming should be independent of modality of presentation, task demands, and variations in context, because the same abstract representation should be activated in all cases. In contrast, episodic accounts hold that repetition priming relies on memory for particular prior episodes. Insofar as repetition effects are due to the retrieval of specific episodic memory traces, they should be very dependent on modality of presentation, task demands, and similarity of linguistic contexts between the first and second presentations of the words. A review of the literature provides evidence for both positions. A subset of the relevant studies is discussed in the following paragraphs.

Within modality repetition priming is generally found to be of larger magnitude than cross-modal repetition priming (Clarke & Morton, 1983; Jacoby & Dallas, 1981, Experiment 6; Kirsner & Smith, 1974; Scarborough, Gerard, & Cortese, 1979; Winnick & Daniel, 1970). These results have led to the general consensus that repetition effects are modality specific (Henderson, 1982; but see Monsell, 1985, for counterarguments). By contrast, the effects of changing task demands and linguistic contexts are far more controversial. Whereas a number of experiments have demonstrated repetition priming across tasks (Clarke & Morton, 1983; Jacoby, 1983; Jacoby & Dallas, 1981; Scarborough et al., 1979), other results have underscored the importance of the compatibility between the mental operations performed on the different encounters with the words. For instance, Ratcliff, Hockley, and McKoon (1985, Experiment 2) showed that the long-term component of repetition priming was larger when a lexical decision task was required on both encounters than when the first encounter was in a recognition task and the second in a lexical decision task.

Of main interest in the present study is the effect of the linguistic context on repetition priming. To what extent, if

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[1] Repetition priming involves two components (Monsell, 1985; Ratcliff, Hockley, & McKoon, 1985): a short-term component and a long-term component that can last for days (Feustel, Shiffrin, & Salasoo, 1983; Jacoby & Dallas, 1981). Unless noted, the long-term component is the main focus of the present report.

any, does the similarity of context between the first and second presentations of a word influence the nature of the repetition priming effects obtained? Some results suggest that repetition effects are independent of the linguistic context (Carr, Brown, & Charalambous, 1989; Monsell, 1985). Carr et al. (1989, Experiment 1) asked subjects to read short paragraphs (either coherent or scrambled texts) aloud and measured reading times for each entire passage. Each paragraph was presented twice, either in the same original context (coherent or scrambled) or in the alternative form (coherent or scrambled). They found that the repetition effect on reading time was not influenced by the contextual similarity between the first and second readings. That is, subjects were faster on second reading irrespective of whether the paragraph was first presented in a coherent or scrambled form. From this and other similar experiments, the authors concluded that "when task demands and presentation conditions remain the same, surface and contextual properties are relatively unimportant to repetition effects on perceptual encoding" (Carr et al., 1989, p. 775).

Other results, however, have pointed to the context specificity of repetition priming (Carroll & Kirsner, 1982; den Heyer, 1986; Jacoby, 1983; McKoon & Ratcliff, 1979). In Jacoby's (1983) experiment, for example, words tested subsequently for either perceptual identification or recognition were presented first in isolation, then together with an antonym, or were generated from their antonyms. Perceptual identification was best for words originally presented in isolation and worst for words from the generate condition. The reverse pattern was obtained for recognition. Thus, both tests were sensitive to the context manipulation. However, these results are not so clear-cut, because the attentional demands of the three study tasks also differ, and such differences have been shown to differentially affect subsequent implicit (e.g., perceptual identification or word completion) and explicit (e.g., recognition or recall) memory measures (Besson, Fischler, Boaz, & Raney, 1992; Monsell, 1985). This confound was avoided in Experiment 5 of den Heyer (1986), in which a lexical decision was required on each encounter with the stimuli. Related and unrelated word pairs were presented once and were then repeated five times. Results showed that the repetition effect was substantially diminished when the prime and target words from previously related and unrelated word pairs were re-paired in the last block of trials. Carroll and Kirsner (1982) likewise reported results that favor an episodic account of the repetition effect. Prime and target items were simultaneously presented for a conjoint lexical decision. These pairs were then repeated in the same or different pairing conditions in a test phase consisting of either a lexical decision or a recognition memory task. Performance in both tasks was improved for same-pair stimuli as long as the words in the pair were related. For unrelated word pairs, exact repetition significantly increased recognition performance but had a small, nonsignificant effect, albeit in the same direction, in the lexical decision task.

One of the main obstacles to ascertaining the influence of the linguistic context on repetition priming comes from the variability of the findings, which is probably because of the fact that different tasks were used. A possible solution to this problem is to take advantage of the *event-related potential* (ERP) methodology that has been shown to be a useful tool in the understanding of language and memory processing (see Fischler & Raney, 1991; Kutas, 1988; Kutas & Van Petten, 1988, for extensive reviews).[2] This suggestion is not meant to imply that ERPs are task independent: In fact, both the nature of the task to be performed and the decision-related processes, for instance, have been shown to influence ERP components (see Kutas & Van Petten, 1988). However, without imposing additional task requirements, ERPs can be recorded while subjects silently read words, sentences, or texts. Moreover, task-related decisions, if any, may be delayed so as not to contaminate the ERP components of interest (see Kutas & Hillyard, 1989, for an example). At least two distinct components of the ERPs—the N400 (i.e., a negative component peaking 400 ms after stimulus onset) and the subsequent late positivity—are sensitive to repetition effects (Bentin & Peled, 1990; Besson, Kutas, & Van Petten, 1990, 1992; Karayanidis, Andrews, Ward, & McConaghy, 1991; Nagy & Rugg, 1989; Rugg, 1985, 1987, 1990; Rugg, Furda, & Lorist, 1988; Rugg & Nagy, 1987; Smith & Halgren, 1987, 1989). Thus, ERPs can provide an on-line measure of word repetition effects.

The N400 component has been shown to be sensitive to a number of variables, such as word class (larger N400s to content as opposed to function words; see Besson, Kutas, & Van Petten, 1992; Garnsey, 1985), word frequency (larger N400s to low as opposed to high frequency words; see Besson, Kutas, & Van Petten, 1992; Rugg, 1990; Van Petten & Kutas, 1990), word concreteness (larger N400s to concrete as opposed to abstract words; see Paller, Kutas, Shimamura, & Squires, 1987), semantic relatedness within word pairs (larger N400s to target words unrelated to the prime; see Bentin, McCarthy, & Wood, 1985; Besson, Fischler, et al., 1992; Brown & Hagoort, 1993; Kutas & Hillyard, 1989), word's cloze probability (larger N400s to words unexpected within a sentence context; see Kutas & Hillyard, 1984; Kutas, Lindamood, & Hillyard, 1984), and word repetition (larger N400s to first as opposed to second presentation of the words; see Besson, Kutas, & Van Petten, 1992; Rugg, 1987; Smith & Halgren, 1987, 1989; Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991). Taken together, these results clearly point to the N400 as a good index of semantic expectancy.

Late positive components (LPC) have been observed in many different experiments, revealing sensitivity to a large number of variables. Accordingly, it has been proposed that the variations in LPC amplitude may reflect "context updating" (Donchin, 1981; Donchin & Coles, 1988), contextual

[2] Variations in brain electrical activity associated with stimulus presentation are recorded from the scalp for a certain duration (2,200 ms in the present experiment). Recordings are then averaged according to the experimental conditions; whereas the random variations in brain electrical activity (noise) are eliminated from the resulting averages, the brain activity time-locked to stimulus presentation forms the event-related potential.

closure (Verleger, 1988), or elaborative processes (Neville, Kutas, Chesney, & Schmidt, 1986; see Discussion for more details).

Previously, we examined the effects of repetition on both cued-recall performance and ERPs for congruous and incongruous endings (Besson, Kutas, & Van Petten, 1990, 1992). Specifically, we tested the hypothesis that the amplitude of the N400 component elicited by incongruous words would decrease as the predictability of the words increased. Increased predictability was manipulated by repetition. Results showed that cued recall of both congruous and incongruous words did increase with repetition. In addition, we found that the N400 decreased in amplitude with one repetition of the entire sentence and vanished with a second repetition. Although such results may reflect the strengthening relationship between the incongruous terminal word and the sentence context in which it appears, N400 reduction may instead reflect a higher activation (a lower threshold) of the incongruous word's logogen with repetition, independent of the word's context. And indeed, a sentence context is not a necessary condition for a reduction in N400 amplitude, because similar results have been obtained with the repetition of words in isolation (Nagy & Rugg, 1989; Rugg, 1985, 1987, 1990; Rugg et al., 1988; Rugg & Nagy, 1987; Smith & Halgren, 1987, 1989).

In the present experiment, we examined the effects of linguistic context on repetition priming by repeating the sentence context, the final word, both, or neither; Table 1 illustrates the four conditions. This design is similar in concept to the same versus different pairing conditions used in previous experiments, except that sentence fragments rather than single words serve as contexts. Sentences terminated by low cloze probability words were presented once and then were repeated in one of the four experimental conditions. Insofar as linguistic context influences word repetition effects, larger facilitation (i.e., better cued recall and smaller N400) should be observed for terminal words repeated in the same context than in a different sentence context. On the other hand, if the word repetition effect is nothing but a function of the activation of a word's mental representation, then facilitation should be larger for repeated than unrepeated words regardless of the context.

Table 1
Sample Set of Sentences Presented in the Different Conditions in the Experiment

Sentence	Cued-recall
Nonhomographs	
First presentation	1
Marie fait des galettes de froment	*Marie fait des galettes de. . . .*
It is a nice day to go sailing	
Dans la nuit il aperçoit un renard	*Dans la nuit il aperçoit un. . . .*
She found some good mushrooms	
Paul a été effrayé par la nouvelle	*Paul a été effrayé par la. . . .*
I have met him in this museum	
Second presentation	2
SC/SW: *Marie fait des galettes de froment*	*Marie fait des galettes de. . . .*
It is a nice day to go sailing	
DC/SW: *Elle a un beau manteau en renard*	*Elle a un beau manteau en. . . .*
She did not like mushrooms	
SC/DW: *Paul a été effrayé par la vitesse*	*Paul a été effrayé par la. . . .*
I have met him in this bar	
DC/DW: *Elle a donné ce texte à son éditeur*	*Elle a donné ce texte à son. . . .*
He often practices his piano	
Homographs	
First presentation	1
Francis choisit une banane dans le régime	*Francis choisit une banane dans le. . . .*
John checked the time on his watch	
Cet enfant ressemble à un petit page	*Cet enfant ressemble à un petit. . . .*
The bicycle mechanic replaced the spoke	
Cette mélodie se termine par un sol	*Cette mélodie se termine par un. . . .*
The losing gambler asked for a new deck	
Second presentation	2
SC/SM: *Francis choisit une banane dans le régime*	*Francis choisit une banane dans le. . . .*
John checked the time on his watch	
DC/SM: *Près du roi il y avait son page*	*Près du roi il y avait son. . . .*
He did cut his hand on the spoke	
DC/DM: *En courant il est tombé sur le sol*	*En courant il est tombé sur le. . . .*
The sailor was ordered to scrub the deck	

Note. English sentences are provided to illustrate the design but are not translations of the sentences. SC/SW = same context/same word; DC/SW = different context/same word; SC/DW = same context/different word; DC/DW = different context/different word (control sentences); SC/SM = same context/same meaning; DC/SM = different context/same meaning; DC/DM = different context/different meaning.

A second aim of the present study concerned the question of exactly which aspects of words (graphemic, phonemic, or semantic) are critical for yielding repetition effects. The importance of repeating a word's meaning has been demonstrated by Feldman and Moskovljevic (1987), who capitalized on the fact that Serbo-Croatian is transcribed in two different and equally familiar alphabets (Roman and Cyrillic). They found that repetition priming in a lexical decision task was equally large for words repeated in either alphabet and concluded that the repetition effect was more dependent on the repetition of the semantic than the visual features. We examined this issue by using sentences that ended with ambiguous words (homographs). In this way, the meaning of words could be manipulated while the orthographic and phonemic properties of the words could be held constant.

As with the nonhomographs, sentences terminated by homographs were presented once and then were repeated in one of three experimental conditions: (a) The sentence was repeated in its entirety; (b) the sentence context was different but biased the same meaning of the homograph; or (c) the sentence context was different and biased a different meaning of the homograph (see Table 1). If sentence context influences repetition priming, then facilitation should be larger (i.e., better cued recall and smaller N400) for homographs repeated in the same context than in a different context. Furthermore, if repetition of a word's meaning is essential for eliciting the repetition effect, independent of the sentence context, the facilitation should be larger when the same meaning of the word is repeated (i.e., different context/same meaning) than when a different meaning is biased (i.e., different context/different meaning).

An additional aim of this study was to examine ERP differences related to memory. Results of several experiments have shown that the ERPs to words that are later remembered are associated with larger late positivities than the ERPs to words that are later not remembered; this positive difference related to memory has been labeled the *Dm effect* (Fabiani, Karis, & Donchin, 1990; Karis, Fabiani, & Donchin, 1984; Neville et al., 1986; Paller, 1990; Paller, Kutas, & Mayes, 1987). In other words, differences in word processing that occur during encoding are predictive of subsequent memory performance (Paller, 1990; Paller, Kutas, & Mayes, 1987). Because the word repetition effect lies at the interface between word recognition and memory, it provides an interesting tool for studying the relationship between the cognitive operations that allow lexical identification and word retrieval. The design of the present experiment allowed us to investigate the extent to which the Dm effect is modulated by the various repetition conditions. The finding of an interaction would further support the hypothesis that some common process underlies the ERP repetition and memory effects.

Method

Subjects

Twenty (11 women and 9 men) native French speakers (mean age = 24.7 years, range = 19–32 years) were paid for their participation in two 3-hr sessions separated by 2 days. The data from 2 subjects were discarded because of technical problems. All subjects but 1 were right-handed according to self-report and to the Edinburgh Inventory (Oldfield, 1971); 1 of the right-handed subjects had a left-handed relative in his immediate family. All subjects had normal or corrected-to-normal vision.

Materials

Eight hundred and fifty sentences were generated for this experiment, of which 400 sentences ended with unambiguous words (nonhomographs) and 450 sentences ended with ambiguous words (homographs). One hundred and fifty ambiguous words were selected either from French normative tables (*Table de répartition des homographes*; Institut National de la Langue Française, 1971) or an etymological dictionary. Three sentences were generated for each ambiguous word: two biasing the same meaning and a third biasing an alternative meaning of the homograph.

To obtain estimates of the cloze probabilities (Taylor, 1953) of the sentence final words, we divided the set of sentences into two lists of 425 sentences each. Each list was presented to a group of 26 subjects who did not participate in the ERP experiment. These subjects were asked to complete each sentence fragment with the first word that came to mind, to avoid proper nouns and repetitions, and to complete the questionnaire at their own pace but without going back in the list. This task took about 1 hr.

Overall, the cloze probability of the terminal homographs and nonhomographs was low ($p < .30$ and $p < .28$, respectively). Homograph sentences ranged from 5 to 12 words in length (mean number of words = 8.4), and nonhomograph sentences ranged from 5 to 13 words (mean number of words per sentence = 8.8). Final sentence words comprised 3 to 12 letters (mean number of letters = 7.7).

Design

Nonhomographic sentences. One hundred and fifty nonhomographic sentences were presented and were then repeated in one of three different conditions: (a) *same word/same context*, in which 50 nonhomographs were repeated in their original contexts; (b) *same word/different context*, in which 50 nonhomographs were repeated in different sentence contexts; and (c) *different word/same context*, in which 50 different nonhomographs were presented in repeated sentence contexts. In addition, 50 new sentences were included as control sentences in a *different word/different context* condition.

To control for item variance, we constructed four different lists so that, across lists, each sentence occurred in each of the repetition conditions. Each list was presented to a different group of subjects and comprised 350 sentences.[3] No one subject saw the same sentence frame in more than one condition.

[3] Of the 350 sentences presented in each list, 250 were new sentence contexts (first presentation, 150; different context/same word, 50; and control sentences, 50) and 100 were old sentence contexts (same context/same word, 50; and same context/different word, 50). Similarly, of the 250 new terminal words presented (first presentation, 150; same context/different word, 50; and control condition, 50), 100 words were repeated (same context/same word, 50; and different context/same word, 50). Note that for each sentence to be presented in each of the repetition condition across lists, a set of 50 new sentence contexts ended with an old terminal word (different context/same word), and a set of 50 new words ending repeated sentence contexts (same context/different word) had to be built for each list. Consequently, 400 nonhomographic sentences were used across subjects in the experiment.

Homograph sentences. An additional set of 150 sentences ending in homographs was presented once and was then repeated in one of three different conditions: (a) *same context/same meaning*, in which 50 homographs were repeated in their original context; (b) *different context/same meaning*, in which 50 homographs were repeated in sentence contexts that, although different from the original context, nonetheless biased the same meaning of the homograph as on its initial presentation; and (c) *different context/different meaning*, in which 50 homographs were repeated but in different sentence contexts that biased an alternative meaning than on initial presentation.

To control for item variance, we constructed three different lists so that, across lists, each sentence occurred in each of the repetition conditions. Each list was presented to a different group of subjects and comprised 300 sentences.[4] No one subject saw the same sentence frame in more than one condition.

Procedure

Six hundred and fifty sentences were presented across the two sessions, with 300 sentences ending in homographs and 350 sentences ending in nonhomographs. Each session comprised four blocks of trials; homograph and nonhomograph sentences were randomly intermixed within each block, as were the different repetition conditions.

Sentences were presented one word at a time, in the center of a computer screen placed 60 cm in front of the subject. Each word was written in uppercase and was presented for 200 ms, with a stimulus onset asynchrony between words of 500 ms. The intersentence interval was 2 s. The experiment was under the control of an Olivetti M240 personal computer.

At the beginning of the first session, subjects were informed that they would be presented with series of sentences that they should read silently for comprehension. In addition, they were asked to attempt to memorize the final word of each sentence in anticipation of a subsequent cued-recall memory test. They were also asked to avoid blinking for about 2 s from the onset of the sentence terminal word; they were trained to blink during the intersentence interval. After the instructions, the subjects saw a practice set of 10 sentences. The first block of sentences was then presented, followed by a cued-recall memory test. For the memory test, sentences were presented in the same order as their original occurrence but appeared on the screen in their entirety with the exception of the final word. Subjects were asked to say aloud the word they recalled as having previously completed the sentence. They had 5 s to give their response. The ERPs were not recorded while the subjects performed the cued-recall memory test.

Before the second presentation of the sentences (Block 2), subjects were told that whereas some sentences were to be repeated, others were new, but that this did not involve any specific action on their part. A cued-recall memory test followed the presentation of the sentences. The same procedure for Blocks 1 and 2 was then repeated with a new set of sentences (Blocks 3 and 4). It is important to note that, over the entire experiment, sentence contexts were presented four times in the same context/same word and same context/different word conditions (Block 1, Cued-Recall 1, Block 2, and Cued-Recall 2) but only twice in the different context/same word (Block 1 and Cued-Recall 1) and different context/different word conditions (Block 2 and Cued-Recall 2).

Recordings

Electroencephalogram (EEG) was recorded by means of Ag/AgCl electrodes from six scalp sites: two along the midline, central (Cz) and parietal (Pz; Jasper, 1958), and two lateral pairs over anterior-temporal (10% of the interaural distance lateral to Cz and 20% of the distance between this point and frontal (fPz) on the left and on the right) and posterior-temporal regions (30% of the interaural distance lateral to Cz and 12.5% of the inion-nasion distance posterior to Cz, on the left and on the right), each referred to the left mastoid. An electrode was placed on the right mastoid, and it was also referred to the left mastoid. Eye movements and blinks were monitored by an electrode on the lower orbital ridge referred to the left mastoid.

The EEG was amplified by Grass P5 RPS107 amplifiers with a 0.01 to 30 Hz (half-amplitude cutoff) bandpass. The sampling rate was 250 Hz. Approximately 10% of the trials were contaminated with eye movements or muscle artifacts; these were rejected off-line. Electrode impedances never exceeded 3 kilo-ohms.

Data Analysis

The ERPs were averaged off-line for a 2,200-ms epoch within each condition for each subject and were time-locked to the onset of the sentence terminal words. We analyzed the ERP data by computing the mean amplitude in selected latency windows in relation to a 200-ms prefinal word baseline. To be consistent with previous literature, we measured the N400 and the subsequent positivity in the 300–600-ms and the 600–1,200-ms ranges, respectively. Repeated measures analyses of variance (ANOVAs) were carried out with the Greenhouse-Geisser correction for inhomogeneity of variance applied where appropriate; reported are the uncorrected degrees of freedom, the epsilon value, and probability level following correction. Unless specified, Tukey honestly significant difference (HSD) tests were used to test the significance of post hoc comparisons.

Results

ERPs to the First Sentence Presentation

Large N400 components with the typical posterior maximum are elicited by homographic and nonhomographic terminal words on initial presentation. A two-way ANOVA, including word type (homograph vs. nonhomograph) and electrode (six levels) as variables showed no significant effect of word type: 300–600 ms, $F(1, 17) = 2.78, p > .10$, $MS_e = 3.00$; and 600–1,200 ms, $F < 1$. But there was a significant main effect of electrodes, $F(5, 85) = 7.40, p < .001$, $MS_e = 1.74$, epsilon = .46. Results of post hoc Tukey (HSD) tests indicated that the N400s were significantly

[4] Of the 300 sentences presented in each list, 250 were new sentence contexts (first presentation, 150; different context/same meaning, 50; and different context/different meaning, 50) and 50 were repeated sentences (same context/same meaning). On the other hand, the 150 homographs were repeated in sentence contexts that biased either the same meaning as on first presentation (same context/same meaning and different context/same meaning) or a different meaning (different context/different meaning). Note that for each sentence to be presented in each of the repetition conditions across lists, a set of 100 new sentence contexts ending with a repeated homograph (different context/same meaning and different context/different meaning) had to be built for each list. Consequently, 450 nonhomographic sentences were used across subjects in the experiment.

larger centro-parietally (Cz = 1.04 μV and Pz = 0.24 μV) and at posterior lateral sites (left = –0.13 μV and right = –0.48 μV) than at anterior lateral sites (left = 0.58 μV and right = 0.91 μV).

Repetition Effects

As can be seen in Figure 1, there was a significant decrease in N400 amplitude with exact sentence repetition for both nonhomographs and homographs: main effect of repetition in the 300–600-ms latency band, $F(1, 17) = 44.44, p < .001$, $MS_e = 18.06$; and Repetition × Electrode interaction, $F(5, 85) = 14.60$, $p < .001$, $MS_e = 1.96$, epsilon = .35. The repetition effect was larger at centro-parietal and posterior lateral sites than at anterior sites (see Table 2).

Nonhomographs. As can be seen in Figure 2, the ERPs in the four different repetition conditions diverge around 170 up to 750 ms after terminal word onset, with the smallest N400s associated with the exact repetition condition, the largest N400s in the different context conditions (different context/same word and different context/different word), and N400s of intermediate amplitude in the same context/different word condition. The ANOVAs, including repetition type (exact repetition vs. different context/same word vs. same context/different word vs. different context/different word) and electrode (six levels) as variables, showed a significant main effect of repetition type in the 300–600-ms range, $F(3, 51) = 9.96, p < .001, MS_e = 8.82$, epsilon = .84. Results of Tukey (HSD) tests showed that the N400s in the exact repetition condition (2.97 μV) were significantly smaller (i.e., the mean amplitude in the 300–600-ms range was more positive) than the N400s in both the different context/same word (1.01 μV) and the different context/different word (1.18 μV) conditions but were not different from the N400s to different words in repeated context (same context/different word = 2.04 μV). Furthermore, the N400s in this last condition were not different from those in either the different context/same word or the different context/different word conditions. The Repetition Type × Electrode interaction was also significant, $F(15, 255) = 2.89$, $p < .02$, $MS_e = 1.64$, epsilon = .28, with the differences being largest posteriorly and slightly larger over the right than the left hemisphere (see Table 3). No significant differences were found between 600 and 1,200 ms ($F < 1$).[5]

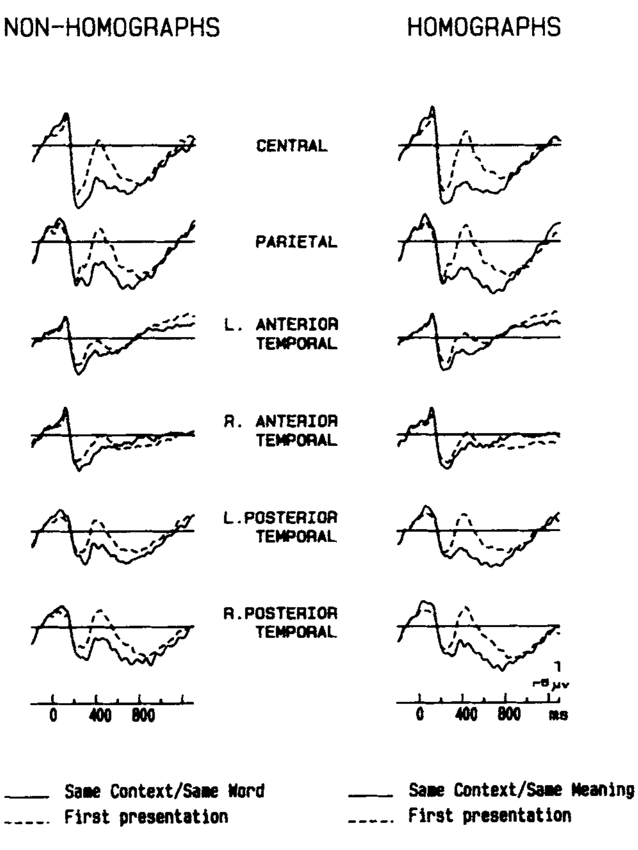

Figure 1. Grand average event-related potentials ($N = 18$) for nonhomograph and homograph endings on first presentation of the sentences (number of trials contributing to the averages [n]: for nonhomographs, $n = 2,445$; for homographs, $n = 2,502$) and in the exact repetition condition (nonhomographs: same context/same word, $n = 830$; homographs: same context/same meaning, $n = 838$). (In this and subsequent figures, traces corresponding to each recording site are presented and negative is up.)

Table 2
Distribution of the Repetition Effect Between 300 and 600 Milliseconds for Both Nonhomograph and Homograph Endings

Sentence	Cz	Pz	LAT	RAT	LPT	RPT
Nonhomographs						
M	3.74	3.33	1.02	1.19	2.44	2.80
SD	3.51	2.70	1.66	1.78	1.96	2.06
Homographs						
M	4.68	4.08	1.71	0.93	3.41	3.35
SD	2.51	2.42	1.31	1.67	2.01	2.03

Note. Repetition effect is the difference in N400 mean amplitude (μV) between first presentation and exact repetition. Cz = central; Pz = parietal; LAT = left anterior temporal; RAT = right anterior temporal; LPT = left posterior temporal; and RPT = right posterior temporal.

[5] The repetition effects can be measured in two different ways, because either the new sentences presented in the different context/different word condition or the first presentation of the sentences may serve as control. In the analyses reported earlier, the data from the different context/different word condition were used as controls. We also performed parallel analyses by using the data from the sentences on first presentation. Similar results were obtained. In the 300–600-ms range, both the main effect of repetition type and the Repetition × Electrode interaction were significant, $F(3, 51) = 13.39$, $p < .001$, epsilon = .78, and $F(15, 255) = 3.86$, $p < .007$, epsilon = .25, respectively. The N400s in the exact repetition condition (same context/same word) were significantly smaller than both the N400s in the different context/same word condition and the N400s elicited on first sentence presentation, but they were not different from the N400 to different words in repeated context (same context/different word). In the 600–1,200-ms range, the main effect of repetition type was not significant, $F(3, 51) = 1.21$, $p > .20$.

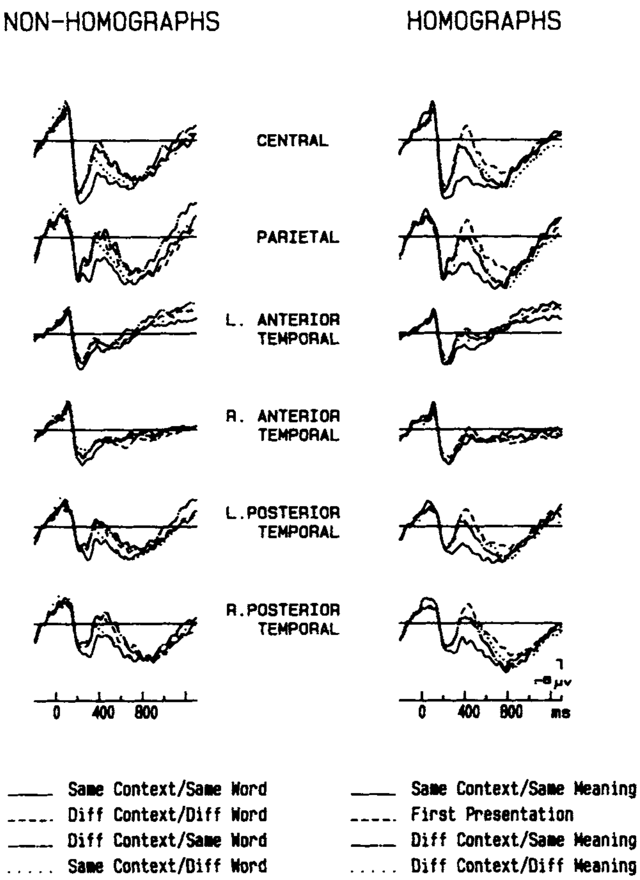

Figure 2. Overlapped are the event-related potentials for nonhomograph and homograph endings on second presentation in the different conditions of the experiment. (For nonhomographs: same context/same word, n = 830; different [Diff] context/different word, n = 862; different context/same word, n = 824; same context/different word, n = 821. For homographs: same context/same meaning, n = 838; first presentation, n = 2,502; different context/same meaning, n = 882; and different context/different meaning, n = 827.)

It is clear from Figure 2 that initially (from 200 ms to 350 ms), the N400s to different words in repeated sentence contexts (same context/different word) are identical to the N400s generated in the two different-context conditions (different context/same word and different context/different word). However, after 350 ms the traces diverge and the N400s in the same context/different word condition more closely resemble the N400s in the exact repetition condition. Because the 300–600-ms latency window is too broad to reveal the varying time courses of these repetition effects, a more fine-grained analysis of successive 25-ms epochs of the ERPs from 200 ms to 725 ms was carried out.

The N400s elicited in the exact repetition condition are significantly different from the N400s generated in the same context/different word condition from 225 ms to 400 ms (see Table 4). From 400 ms to 675 ms, the ERPs are similar in both the exact repetition and in the same context/different word conditions but are significantly different from those in the different context/same word condition (see Table 4).

Sentence context versus terminal word. To independently examine the effects of repeating just the sentence context (repeated vs. different) from the effects of repeating just the sentence terminal words (repeated vs. different), we resorted the ERPs into four different averages: repeated context (same context/same word and same context/different word conditions), different context (different context/same word and different context/different word conditions), repeated word (same context/same word and different context/same word conditions), and different word (same context/different word and different context/different word conditions). As can be seen in Figure 3, context repetition effects are larger and more extended than are terminal word repetition effects.

Two-way ANOVAs, in the 300–600-ms range with either the context (repeated vs. different) or the terminal word (repeated vs. different) as one variable and electrode (six levels) as another, revealed significantly larger N400s to different (1.10 μV) than to repeated (2.51 μV) contexts: main effect of context, $F(1, 17) = 23.09, p < .001, MS_e = 4.66$, but no effect of terminal word (repeated vs. different), $F(1, 17) = 2.08, p > .10, MS_e = 3.77$. However, a close inspection of the traces revealed that the effects of terminal word were not only smaller but also more restricted in time. Consequently, a two-way ANOVA was also conducted in a more narrow latency band: 200–450 ms. Results showed that same words (2.90 μV) were associated with significantly smaller N400s

Table 3
Mean Amplitude (μV) of the Event-Related Potentials Between 300 and 600 Milliseconds for Nonhomograph Endings in the Different Conditions for Each Electrode Location

Condition	Cz	Pz	LAT	RAT	LPT	RPT	*M*
First presentation							
M	1.43	0.37	0.99	0.90	0.09	−0.45	0.55
SD	1.85	1.70	1.42	1.65	1.62	1.88	1.77
SC/SW							
M	5.17	3.70	2.01	2.09	2.53	2.35	2.97
SD	3.12	2.73	1.91	1.91	2.30	2.24	2.61
DC/SW							
M	2.29	0.71	1.25	1.54	0.41	−0.11	1.01
SD	3.10	2.51	2.11	2.10	2.38	2.47	2.54
SC/DW							
M	3.62	2.13	1.82	1.45	1.73	1.50	2.04
SD	2.53	2.07	1.96	2.13	2.17	1.88	2.21
DC/DW							
M	2.12	1.12	1.16	1.56	0.72	0.40	1.18
SD	2.35	1.88	2.18	2.72	1.75	2.13	2.21

Note. Cz = central; Pz = parietal; LAT = left anterior temporal; RAT = right anterior temporal; LPT = left posterior temporal; and RPT = right posterior temporal. SC/SW = same context/same word; DC/SW = different context/same word; SC/DW = same context/different word; DC/DW = different context/different word.

than different words, 2.16 μV, $F(1, 17) = 9.55$, $p < .006$, $MS_e = 3.07$.

Homographs. As can be seen in Figure 2, a large decrease in N400 amplitude is obtained with exact repetition relative to both first presentation and to the other repetition conditions (different context/same meaning and different context/different meaning).

The ANOVAs, including presentation (first presentation vs. exact repetition vs. different context/same meaning vs. different context/different meaning) and electrode (six levels) as variables, showed a significant main effect of presentation in the 300–600-ms range, $F(3, 51) = 19.51$, $p < .001$, $MS_e = 8.94$, epsilon = .81. Post hoc Tukey (HSD) tests confirmed that the N400s in the exact repetition condition (3.19 μV) were significantly smaller than those in any of the other conditions, which did not differ from one another (first presentation = 0.16 μV; different context/same meaning = 1.21 μV; and different context/different meaning = 1.15 μV). This, however, interacted with electrode location: Presentation × Electrode interaction, $F(15, 255) = 5.58$, $p < .001$, $MS_e = 1.27$, epsilon = .38. Indeed, N400s in both the different context conditions (different context/same meaning and different context/different meaning) were significantly smaller than the N400s elicited on initial presentation, at midline centro-parietal sites (see Table 5). No significant differences were found between 600 and 1,200 ms ($F < 1$).[6]

Table 4
Results of the Analysis of Variance Conducted in Successive 25-Millisecond Epochs of the Event-Related Potentials From 200 to 725 Milliseconds for Nonhomograph Endings

	SC/SW vs. SC/DW		DC/SW vs. SC/DW	
Epoch (ms)	*F*	*p*	*F*	*p*
200–225	3.46	.08		*ns*
225–250	4.44	.05		*ns*
250–275	4.91	.04		*ns*
275–300	5.38	.03		*ns*
300–325	13.27	.002		*ns*
325–350	17.86	.006		*ns*
350–375	11.05	.004		*ns*
375–400	5.23	.03	2.98	.10
400–425	2.91	.10	5.34	.03
425–450	2.14	.16	5.22	.03
450–475		*ns*	10.81	.004
475–500		*ns*	13.20	.002
500–525		*ns*	5.85	.02
525–550		*ns*	5.88	.02
550–575		*ns*	18.22	.005
575–600		*ns*	11.35	.003
600–625		*ns*	7.51	.01
625–650		*ns*	6.61	.01
650–675		*ns*	7.23	.01
675–700		*ns*	3.34	.08
700–725		*ns*	1.91	.18

Note. SC/SW = same context/same word (exact repetition); SC/DW = same context/different word; DC/SW = different context/same word.

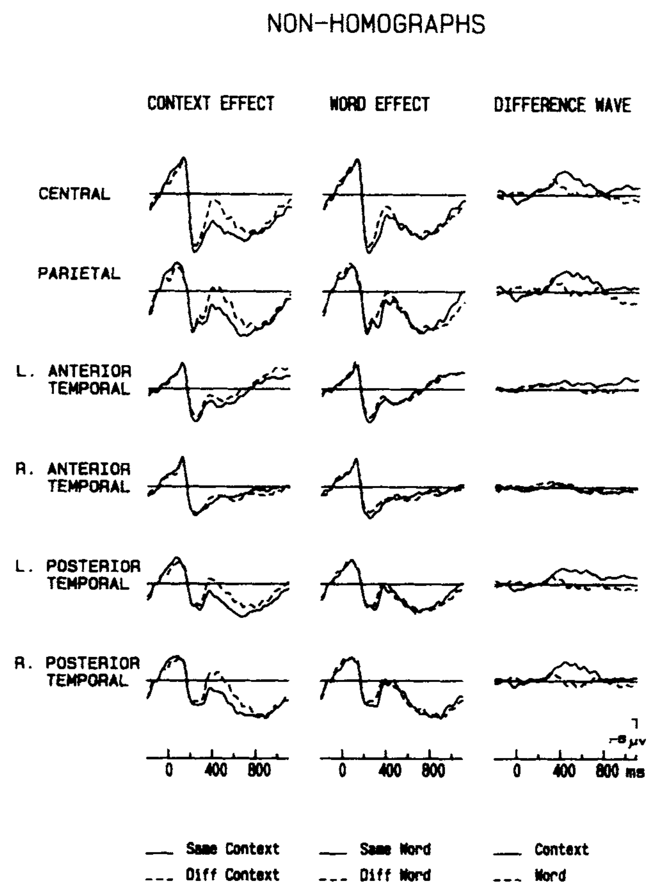

Figure 3. For nonhomograph endings, the effect of context (same [n = 1,651] vs. different [Diff; n = 1,686]) is illustrated in the left-hand column; the effect of terminal word (same [n= 1,654] vs. different [n = 1,683]) is illustrated in the middle column; and the effect of context (same minus different) is compared with the effect of terminal words (same minus different) in the right-hand column.

Cued-Recall Performance

Overall, cued-recall performance was rather low following the first presentation of the sentences (homographs = 52% and nonhomographs = 42%), probably because of the low cloze probabilities of the terminal words. Recall performance increased substantially for both homograph (80%) and nonhomograph (72%) endings repeated in the same sentence contexts.

[6] An analysis of variance including only the three repetition conditions (same context/same meaning vs. different context/same meaning vs. different context/different meaning) and electrode location was conducted. The results were similar to those including ERP from initial presentation. In the 300–600-ms range, the main effect of repetition type was significant, $F(2, 34) = 13.21$, $p < .001$, epsilon = .95, as was the Repetition × Electrode interaction, $F(10, 170) = 4.87$, $p < .001$, epsilon = .44. In the 600–1,200-ms range, the main effect of repetition type was not significant ($F < 1$).

Table 5
Mean Amplitude (μV) of the Event-Related Potentials Between 300 and 600 Milliseconds for Homograph Endings in the Different Conditions for Each Electrode Location

Condition	Cz	Pz	LAT	RAT	LPT	RPT	*M*
First presentation							
M	0.64	0.12	0.16	0.93	−0.35	−0.50	0.16
SD	2.08	2.16	1.32	1.65	1.74	1.74	1.83
SC/SM							
M	5.32	4.20	1.87	1.86	3.06	2.85	3.19
SD	2.94	2.69	1.31	1.69	2.29	2.32	2.55
DC/SM							
M	2.45	1.46	0.62	1.52	0.72	0.46	1.21
SD	2.58	2.60	2.40	1.73	1.81	2.36	2.33
DC/DM							
M	2.44	1.47	0.98	1.39	0.49	0.16	1.15
SD	2.74	2.05	2.40	1.49	1.81	1.89	2.18

Note. Cz = central; Pz = parietal; LAT = left anterior temporal; RAT = right anterior temporal; LPT = left posterior temporal; and RPT = right posterior temporal. SC/SM = same context/same meaning (exact repetition); DC/SM = different context/same meaning; DC/DM = different context/different meaning.

A two-way ANOVA, including word type (homographs vs. nonhomographs) and repetition (first presentation vs. exact repetition) as variables, showed a significant effect of word type, with the homographs (66%) being better recalled than the nonhomographs (57%), $F(1, 17) = 21.82, p < .001, MS_e = 64.54$, and a significant effect of repetition, $F(1, 17) = 497.10, p < .001, MS_e = 30.51$, but no interaction between the two ($F < 1$).

Separate one-way ANOVAs were performed for the nonhomographs and the homographs. For the nonhomographs, the main effect of repetition was significant, reflecting the fact that these were best recalled under exact repetition: same context/same word (72%), $F(3, 51) = 37.58, p < .001, MS_e = 69.12$. Results of the Tukey tests also showed that changing the context led to equally poor recall whether or not the final word was repeated (different context/same word = 46%; and different context/different word = 47%); final words in both these conditions were recalled more poorly than new words (or unrepeated words) ending a context occurring for the second time (same context/different word = 58%). For the homographs, the main effect of repetition was also significant, $F(2, 34) = 63.33, p < .001, MS_e = 64.31$, reflecting the fact that the highest recall was of homographs in the exact repetition condition (same context/same meaning = 80%). The different context/same meaning (57%) and different context/different meaning (51%) conditions did not differ from each other.

Averages as a Function of Subsequent Memory Performance

For each subject, the ERPs recorded during first and second sentence presentations were reaveraged according to whether or not the sentence terminal words were recalled in the cued-recall memory test that followed each presentation.

Analysis of Dm for the ERPs recorded during first presentation. As can be seen in Figure 4, on initial presentation, words that were subsequently recalled elicited larger positivities between 200 ms and 1,200 ms than words that were subsequently not recalled. The ANOVAs, including word type (homographs vs. nonhomographs), memory (recalled vs. not recalled), and electrode (six levels) as variables, showed that Dm was significant in both latency bands of interest: 300–600-ms range, $F(1, 17) = 9.29, p < .007, MS_e = 10.98$; and 600–1,200-ms range, $F(1, 17) = 18.91, p < .001, MS_e = 19.96$. Neither the main effect of word type nor the Word Type × Memory interaction was significant.

Distribution of the Dm effect. As can be seen in Figure 4, the difference related to memory has a posterior distribution: Memory × Electrode interaction in the 300–600-ms range, $F(5, 85) = 5.40, p < .009, MS_e = 1.43$, epsilon = .40. Post hoc comparisons showed that Dm was indeed largest at centro-parietal midline locations (Cz = 1.39 μV and Pz = 1.73 μV). The difference between posterior (right posterior-temporal = 1.14 μV and left posterior-temporal = 1.21 μV) and anterior (left anterior-temporal = 0.15 μV and right anterior-temporal = 0.18 μV) regions was not reliable. The Memory × Electrode interaction was also significant in the 600–1,200-ms range, $F(5, 85) = 13.70, p < .001, MS_e = 2.51$, epsilon = .55, and was not different for homographs and nonhomographs ($F < 1$). The distribution of the Dm effect was somewhat different than in the 300–600-ms range in that it was larger at midline (Cz = 2.66 μV and Pz = 2.96 μV) and posterior (left posterior-temporal = 2.48 μV and right posterior-temporal = 2.84 μV) than anterior sites (left anterior-temporal = – 0.26 μV and right anterior-temporal = 0.51 μV).

Analysis of Dm for the ERPs Recorded During Second Presentation

Nonhomographs. Figures 5 and 6 illustrate the ERP differences based on subsequent performance for each of the repetition conditions. Whereas the late positivity was always greater for words later recalled than not recalled, the amplitude of the Dm effect seemed to vary with the repetition condition. The ANOVAs, including repetition condition (same context/same word, different context/same word, same context/different word, and different context/different word), memory (recalled vs. not recalled), and electrode (six levels) as variables, revealed a significant main effect of memory both between 300 and 600 ms and 600 and 1,200 ms, $F(1, 17) = 20.30, p < .001, MS_e = 32.54$ and $F(1, 17) = 14.93, p < .001, MS_e = 39.70$, respectively. The main effect of repetition condition was also significant in the 300–600-ms range, $F(3, 51) = 3.08, p < .03, MS_e = 18.71$, but not in the 600–1,200-ms range ($F < 1$). Likewise, the Repetition Condition × Memory interaction was marginally significant in the 300–600-ms range, $F(3, 51) = 2.34, .05 < p < .10, MS_e = 23.99$, and was not significant in the 600–1,200-ms range ($F < 1$). In this latter range, however, the three-way interaction of Repetition Condition × Memory ×

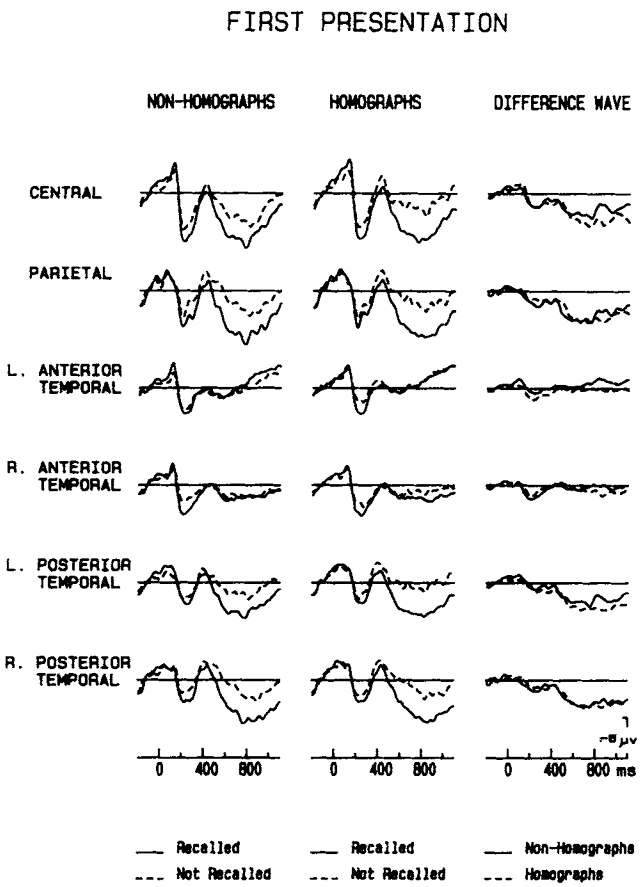

Figure 4. On first presentation, the event-related potentials (ERPs) to words that are subsequently recalled (n = 1,039) are compared with the ERPs to words that are subsequently not recalled (n = 1,406) for nonhomographs (left-hand column) and homographs (middle column: recalled [n = 1,320] and not recalled [n = 1,182]); the effect of memory (recalled minus not recalled) for both nonhomograph and homograph endings is presented in the right-hand column.

Electrode was significant, $F(15, 255) = 2.77, p < .01, MS_e = 3.11$, epsilon = .44.

Although the Repetition Condition × Memory interaction in the 300–600-ms latency band was only marginally significant, partial comparisons were performed to test certain a priori predictions. These comparisons revealed that (a) Dm was significantly larger in the exact repetition (3.22 μV) than when the final word was repeated in a different context (different context/same word = 1.28 μV), $F(1, 17) = 4.73, p < .04, MS_e = 21.39$; (b) Dm did not differ significantly between the exact repetition and the same context/different word (1.59 μV) conditions, $F(1, 17) = 2.00, .15 < p < .20, MS_e = 35.68$; and (c) there was no difference in the Dm effects between the different context/same word (1.28 μV) and the same context/different word (1.59 μV) conditions ($F < 1$). It is interesting to note that whereas the amplitude of the positivity for words subsequently recalled varied as a function of the repetition condition, no such difference was observed in the ERPs for words that were subsequently not recalled, $F(3, 51) = 4.35, p < .009, MS_e = 23.17$, epsilon = 0.84 and $F < 1$, respectively (see Figure 6).

Distribution of the Dm effect. As can be seen in Figure 5, the Dm effect is larger posteriorly than anteriorly: Memory × Electrode interaction for 300–600 ms, $F(5, 85) = 5.77, p < .007, MS_e = 4.06$, epsilon = .38; and for 600–1,200 ms, $F(5, 85) = 11.16, p < .001, MS_e = 4.86$, epsilon = .56. The difference between conditions was generally largest at Cz (see Table 6).

Homographs. The Dm effects for the homographs in the various repetition conditions are presented in Figures 7 and 8. As expected, the ERPs to homographs later recalled were associated with larger positivity than the ERPs to homographs that were later not recalled; on visual inspection, this difference seemed larger in the exact repetition condition than in the other conditions. The ANOVAs, including repetition condition (same context/same meaning, different context/same meaning, and different context/different meaning), memory (recalled vs. not recalled), and electrode (six levels) as variables, showed a significant main effect of mem-

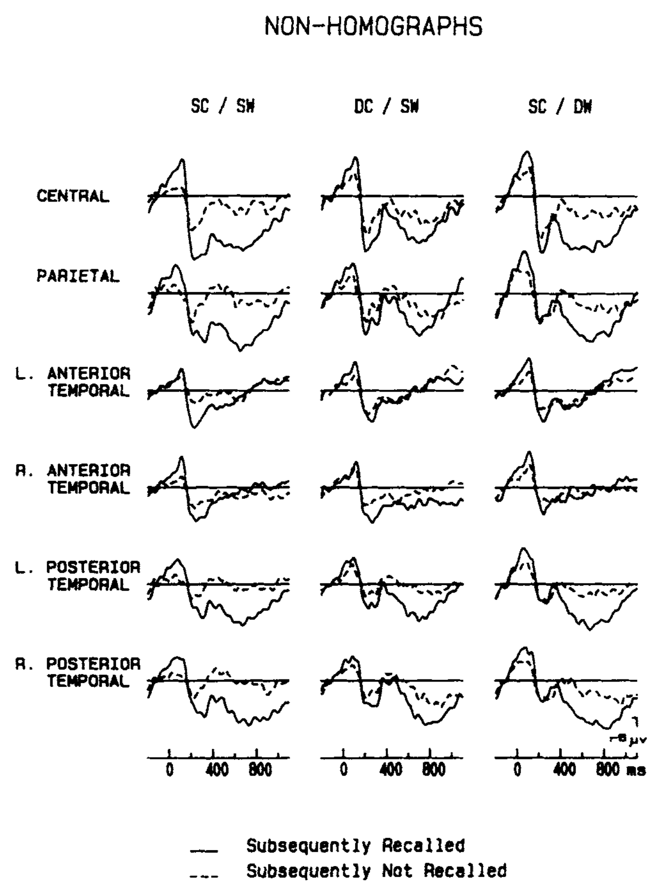

Figure 5. Event-related potentials to nonhomograph endings subsequently recalled and subsequently not recalled in the same context/same word (SC/SW; left-hand column: recalled [n = 602] and not recalled [n = 228]); different context/same word (DC/SW; middle column: recalled [n = 383] and not recalled [n = 441]), and same context/different word (SC/DW; right-hand column: recalled [n = 473] and not recalled [n = 348]) conditions.

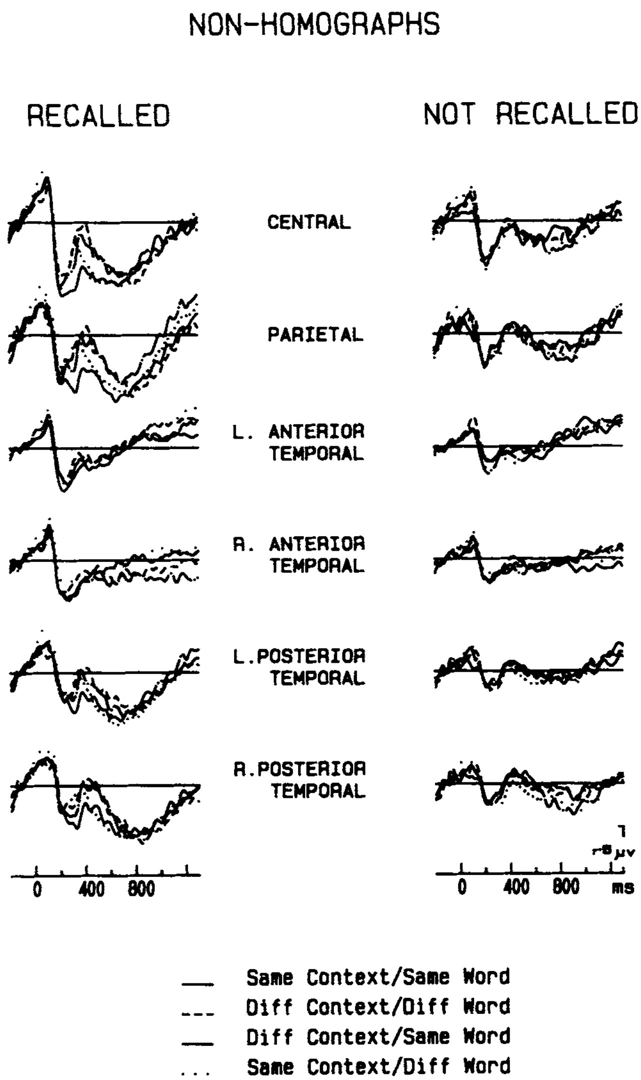

Figure 6. Event-related potentials in the different conditions of the experiment for subsequently recalled (left-hand column) and subsequently not recalled (right-hand column) nonhomograph endings. (Diff = different.)

ory in both the 300–600-ms and the 600–1,200-ms ranges, $F(1, 17) = 23.11, p < .001, MS_e = 24.19$ and $F(1, 17) = 13.07, p < .002, MS_e = 35.76$, respectively. The main effect of repetition, as well as the Repetition × Memory interaction, also was significant in the 300–600-ms range, $F(2, 34) = 7.63, p < .002, MS_e = 13.40$ and $F(2, 34) = 9.23, p < .001, MS_e = 13.91$, respectively. By contrast, neither the main effect of repetition nor the Repetition × Memory interaction was significant in the 600–1,200-ms range ($F < 1$ in both cases).

We performed partial comparisons to further test the Repetition × Memory interaction in the 300–600-ms range. The Dm was larger in the exact repetition condition (same context/same meaning = 3.56 μV) than when the same meaning of a homograph was biased in a different sentence context (different context/same meaning = 1.42 μ V), $F(1, 17) = 14.52, p < .001, MS_e = 17.06$. On the other hand, when the homographs were repeated in different sentence contexts, Dm effects were equivalent whether the same (different context/same meaning = 1.42 μV) or a different (different context/different meaning = 0.57 μV) meaning was biased, $F(1, 17) = 1.14, p = .30, MS_e = 34.28$. Again, it is interesting to note that whereas the amplitude of the positivity for words subsequently recalled was significantly different across repetition conditions, $F(2, 34) = 16.22, p < .001, MS_e = 14.17$, epsilon = .99, no such difference was observed in the ERPs to words that were subsequently not recalled ($F < 1$; see Figure 8).

Distribution of the Dm effect. The ANOVAs in the 300–600-ms range indicated that the Memory × Electrode interaction was significant, $F(5, 85) = 11.79, p < .001, MS_e = 2.48$, epsilon = .49; Tukey tests revealed that Dm was largest at centro-parietal sites. The Memory × Electrode interaction was also significant in the 600–1,200-ms range, $F(5, 85) = 14.01, p < .001, MS_e = 4.71$, epsilon = .41; Dm was larger at centro-parietal and posterior-temporal sites than at anterior-temporal sites (see Table 7).

Table 6
Distribution of the Dm Effect Between 300 and 600 Milliseconds and 600 and 1,200 Milliseconds for Nonhomograph Endings in the Different Conditions for Each Electrode Location

Condition	Cz	Pz	LAT	RAT	LPT	RPT	*M*
300–600 ms							
SC/SW							
M	4.69	4.93	1.67	0.82	3.48	3.70	3.21
SD	4.29	5.14	3.60	2.21	3.37	3.89	4.05
DC/SW							
M	1.68	1.59	0.28	1.17	1.86	1.09	1.28
SD	3.08	4.32	2.26	2.30	3.07	2.48	2.98
SC/DW							
M	3.18	2.04	0.25	0.58	1.77	1.71	1.59
SD	5.16	4.26	2.70	3.33	3.51	4.71	4.06
DC/DW							
M	1.38	0.87	0.61	0.93	0.76	0.83	0.90
SD	4.30	4.86	2.78	4.31	3.33	3.05	3.76
600–1,200 ms							
SC/SW							
M	3.14	3.30	0.02	−1.15	2.67	3.55	1.92
SD	5.79	5.63	2.89	3.50	3.91	4.76	4.79
DC/SW							
M	1.47	0.23	0.68	1.94	1.71	1.85	1.31
SD	3.56	4.43	3.13	3.62	3.49	3.35	3.59
SC/DW							
M	2.50	1.78	−0.83	−0.48	2.36	2.34	1.28
SD	4.98	5.70	2.12	4.52	3.97	6.08	4.84
DC/DW							
M	3.20	2.84	−0.42	1.21	2.40	3.38	2.10
SD	4.54	3.86	3.60	3.70	3.65	3.23	3.93

Note. Dm effect equals the mean amplitude (μV) of recalled minus not-recalled words. Cz = central; Pz = parietal; LAT = left anterior temporal; RAT = right anterior temporal; LPT = left posterior temporal; and RPT = right posterior temporal. SC/SW = same context/same word (exact repetition); DC/SW = different context/same word; SC/DW = same context/different word; DC/DW = different context/different word.

Discussion

Three results are most relevant to the questions raised in the introduction. First, repetition of a sentence final unambiguous word leads to a decrease in N400 amplitude and an increase in cued-recall performance only if the word is repeated in its original context. Second, even when the same meaning of a word is biased when repeated, as in the case of ambiguous words, there is only a slight reduction in N400 amplitude at some electrode sites (midline central and parietal) and no improvement in cued-recall performance if the word is repeated in a different sentence context. Finally, N400 amplitude is not only correlated with repetition but also with subsequent recall; this sensitivity is context dependent.

Abstractionist Versus Episodic Accounts of the Repetition Effect

One goal of the present experiment was to determine the extent to which the decrease in N400 amplitude that accompanied the repetition of incongruous words in previous ex-

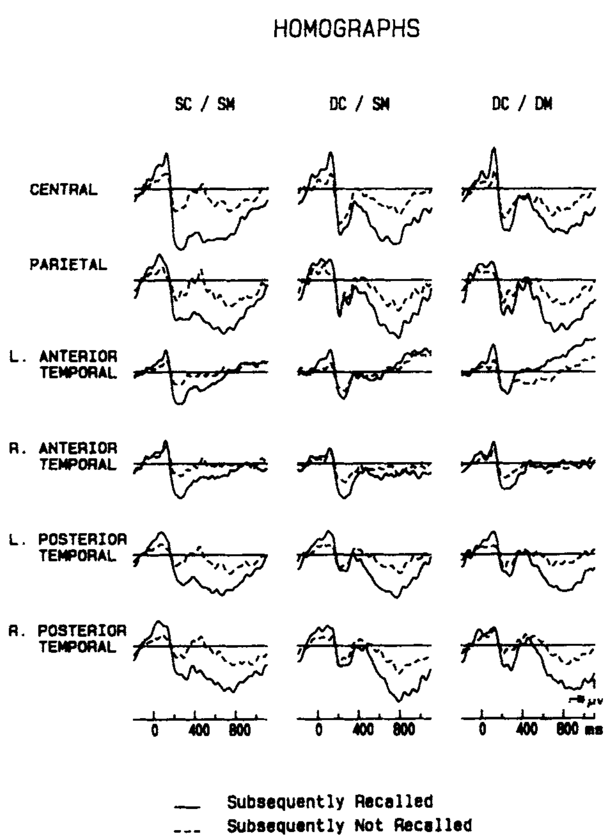

Figure 7. Event-related potentials to homograph endings subsequently recalled and subsequently not recalled in the same context/same meaning (SC/SM; left-hand column: recalled [*n* = 669] and not recalled [*n* = 169]); different context/same meaning (DC/SM; middle column: recalled [*n* = 497] and not recalled [*n* = 385]); and different context/different meaning (DC/DM; right-hand column: recalled [*n* = 442] and not recalled [*n* = 385]) conditions.

Table 7
Distribution of the Dm Effect Between 300 and 600 Milliseconds and 600 and 1,200 Milliseconds for Homograph Endings in the Different Conditions for Each Electrode Location

Condition	Cz	Pz	LAT	RAT	LPT	RPT	*M*
300–600 ms							
SC/SM							
M	5.66	4.49	1.74	2.00	3.72	3.77	3.56
SD	3.09	2.59	2.74	2.49	2.15	2.06	2.84
DC/SM							
M	2.58	1.85	0.11	0.94	1.74	1.31	1.42
SD	3.51	2.71	3.31	2.75	2.77	3.24	3.09
DC/DM							
M	0.89	1.29	−1.37	0.49	0.92	1.22	0.57
SD	3.77	3.09	3.10	3.26	2.82	3.18	3.27
600–1,200 ms							
SC/SM							
M	2.60	2.07	0.09	0.78	1.78	2.52	1.64
SD	3.20	4.78	2.78	2.85	3.16	2.56	3.35
DC/SM							
M	3.25	2.59	−0.47	0.84	2.38	3.17	1.96
SD	4.66	4.06	4.52	3.36	3.18	4.40	4.20
DC/DM							
M	2.50	2.88	−2.39	−0.13	2.83	3.23	1.48
SD	4.18	3.75	3.45	3.68	3.83	3.78	4.24

Note. Dm effect equals the mean amplitude (μV) of recalled minus not-recalled words. Cz = central; Pz = parietal; LAT = left anterior temporal; RAT = right anterior temporal; LPT = left posterior temporal; and RPT = right posterior temporal. SC/SM = same context/same meaning (exact repetition); DC/SM = different context/same meaning; DC/DM = different context/different meaning.

periments (Besson, Kutas, & Van Petten, 1990, 1992) was specific to the repetition of the sentence final word per se or was dependent on the repetition of the sentence context as well. To test these alternatives, we independently manipulated repetitions of terminal words and sentence contexts. However, instead of using incongruous endings to elicit N400s, we used congruous but low cloze probability endings. These have been shown to yield sizable N400 components (Kutas & Hillyard, 1980, 1984; Kutas et al., 1984). As expected, these low cloze probability words did, in fact, elicit large N400 components on initial presentation. Of primary concern here is the sensitivity of N400 amplitude and subsequent cued-recall performance to repetition of only the context (same context/different word), only the final word (different context/same word), or both (same context/same word).

There are two ways to examine the effect of repetition on the ERPs: The ERPs to words in the various repetition conditions can be compared either with the ERPs elicited by these words on their initial presentation or with the ERPs to words presented for the first time during the repetition condition (different context/different word). The choice of control condition did not alter the results or conclusions that were drawn from them. Repeating sentences in their entirety (same context/same word) results in the smallest N400 to terminal words and the best cued-recall performance. These results replicate our previous findings of a large reduction in N400 amplitude when the same sentences are repeated either once or twice (Besson, Kutas, & Van Petten, 1990, 1992). Moreover, they demonstrate unequivocally that both the N400 reduction and the improvement in cued recall are dependent on the repetition of critical words in their original context. Repeating a sentence final unambiguous word in a different context appears to have almost no consequence on either cued-recall performance or the ERPs.

From these results, we conclude that the effect of repetition on N400 amplitude and on performance in an episodic cued-recall memory test is not merely a function of the activation of a word's representation and that linguistic context has a large influence on word repetition priming. One could argue that there is no repetition effect for words that are repeated in different sentence contexts because the different contexts activate and lead to encoding of different aspects of a word's meaning, for example, its "core" versus "peripheral" senses (Barsalou, 1982). McKoon and Ratcliff (1988), in fact, found that subjects were faster to verify sentences that matched a property of the noun that was implied by a paragraph context (e.g., "tomatoes are red") than one that was apt but was not implied (e.g., "tomatoes are round"). Although the different sentence contexts used in the present experiment in the different context/same word condition may have activated different properties of the terminal word's meaning, the results obtained for the homographs are inconsistent with such an interpretation. Whenever the sentence context preceding the repeated homographs was replaced, it made no difference whether the context biased the same meaning of the homograph as the initial context or whether it biased an alternative meaning; the N400s were indistinguishable.

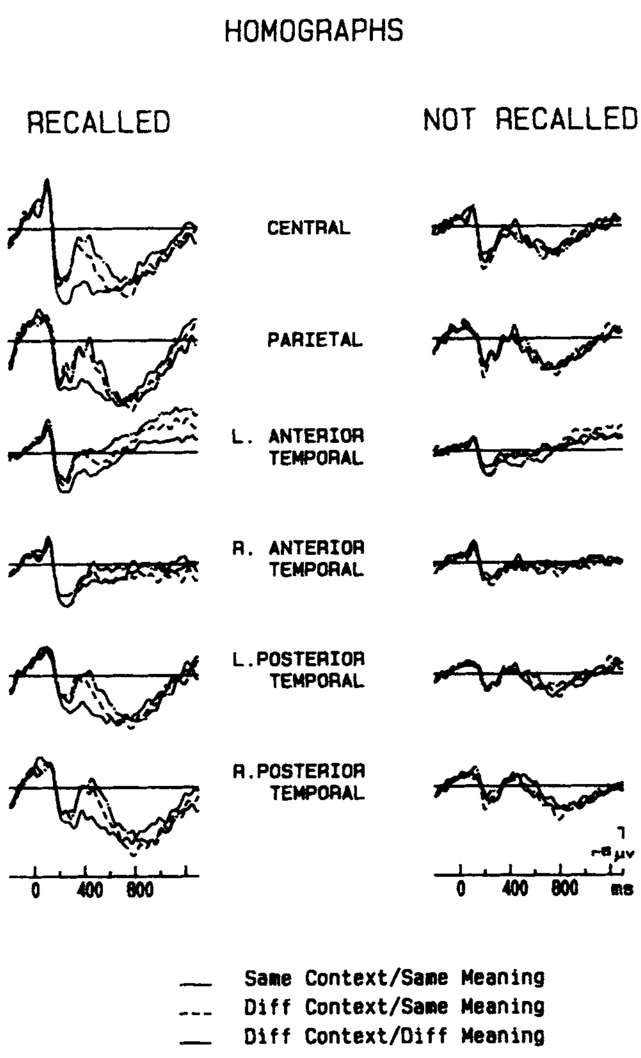

Figure 8. Event-related potentials in the different conditions of the experiment for subsequently recalled (left-hand column) and subsequently not recalled (right-hand column) homograph endings. (Diff = different.)

Although these results point largely to the important role of repeating the same sentence context to attenuate N400 amplitude, the first half of the N400 effect seems to reflect primarily a word's expectancy. That is, between 200 and 400 ms, the ERPs to all but the exact repetition are virtually identical. Note that the exact repetition condition (same context/same word) differs from the others in that it is the only condition in which the repeated word also corresponds to the word expected on the basis of the previous encounter. Thus, although the expectancy for the final word is relatively low if estimated strictly on the basis of contextual constraint, repetition of the sentence context serves to raise that final word's expectancy. By contrast, the expectancies of the final words in the three other repetition conditions remain quite low. This difference in predictability of final words in the four conditions is sufficient to account for the ERP effect in the 200–400-ms range. This conclusion is consistent with previous reports showing that N400 amplitude is modulated by semantic expectancy (Kutas & Hillyard, 1984; Kutas et al., 1984; Kutas & Van Petten, 1988).

The present results indicate that at least the latter half of the N400 may be influenced by processes other than expectancy, such as the mere repetition of the sentence context per se. Thus, the two conditions in which the context is repeated pattern together and are statistically different from the two conditions in which the contexts are not repeated from first presentation. There are several possible explanations for how repeating a context influences the processing of a word so that the associated N400 is reduced. Before considering these, however, some of the less interesting (and less likely) accounts of the reduction in N400 amplitude in the same context/different word condition can be discarded.

Several results in the literature indicate that N400 amplitude is modulated by semantic association or relationship within word pairs, with smaller N400s in response to related as opposed to unrelated targets (Bentin et al., 1985; Besson, Fischler, et al., 1992; Boddy, 1986; Brown & Hagoort, 1993; Fischler, Bloom, Childers, Roucos, & Perry, 1983; Holcomb, 1988; Holcomb & Neville, 1990; Kutas & Hillyard, 1989). Furthermore, Kutas et al. (1984) showed that the N400 to sentence endings is not only sensitive to a word's expectancy but also to semantic relations. Specifically, they found that in sentences of high contextual constraint, incongruous words that were semantically related to the most expected (best) completion were associated with smaller N400s compared with incongruous words that were unrelated to the best completion.

In the same context/different word condition, sentence contexts were completed by different words than on first presentation. If these final words were semantically related (synonyms, for instance) to the words that had ended these same contexts on their initial appearance, we might expect this relation to be reflected in a slightly attenuated N400. Note that this kind of priming effect would have to be relatively long-lived, because the interval between first and second sentence presentations was about 30 min with a cued-recall memory test intervening. Results of several experiments have typically shown that the effects of semantic priming within word lists are rather short-lived, being largely diminished if not eliminated by intervening words (Meyer, Schvaneveldt, & Ruddy, 1975; Ratcliff & McKoon, 1978; Ratcliff et al., 1985). There is, however, evidence based on reaction times, percentage correct, and ERP measures that priming effects have a longer duration when words are embedded in sentences (Foss, 1982; Rothkopf & Coke, 1966; Van Petten, 1989).

Thus, to test for this possibility, we presented 200 word pairs to 10 subjects who did not participate in the ERP experiment; each word pair was derived from the words seen on first and second presentations in the same context/different word condition in each of the four lists. We asked subjects to rate the degree of the semantic relationship between words in each pair on a 5-point scale (1 = *none* and 5 = *strong*). Results showed that 60% of the 200 word pairs were judged by subjects to be not at all or only weakly related, 17% as moderately related, and 23% as related. (It was clear from the results that subjects tended to overestimate the strength of the semantic relationship within word pairs because none of the pairs were strongly related; thus, any pair in which a semantic relationship was present, even if rather weak [e.g., BANANES-RIZ/BANANA-RICE], was likely to be rated as medium or good.) In light of these results, it seems unlikely that the decrease in N400 amplitude to unrepeated words at the end of repeated sentence contexts (same context/different word) compared with different sentence contexts (different context/same word and different context/different word) was primarily a consequence of semantic priming between the original ending and the one on the sentence's second presentation.

An alternative explanation for the reduced N400s in the same context/different word condition might be in terms of semantic priming between the various open class words that constitute the sentence and the final word. For such priming effects to account for the present results, the proportion of sentence endings semantically related to sentence intermediate words has to be higher in the same context/different word condition than in the other conditions (different context/same word and different context/different word), in each of four stimulus lists. A posteriori examination for such a bias did not reveal any obvious difference between the sentences presented in the same context/different word condition and those in the other conditions.

Finally, because the sentences we used were low in contextual constraint, a large number of words may have been activated as possible sentence completions (e.g., Schwanenflugel & Lacount, 1988). Thus, it is possible that the words actually presented on second presentation in the same context/different word condition, even if not semantically related to the word seen on first presentation, might nevertheless have belonged to this set of previously activated words (see Nelson, Gee, & Schreiber, 1992). As far as we know, no empirical evidence exists that would allow a determination of the extent to which such residual, episodically based activation could influence N400 amplitude. This should be the focus of further studies.

Having ruled out explanations of the effects of repeating a context in terms of uncontrolled priming, we turn to two viable accounts of the data: one that links N400 with integration and another that raises the problem of overlapping components. On the integration view, sentence final words are associated with large N400 components on first presentation because these words are relatively unexpected and therefore difficult to integrate within their sentence context. Repetition is associated with a reduction in N400 because it increases the "ease" with which the words are integrated to form a mental representation of the sentence (see Halgren & Smith, 1987; Rugg, 1990; Rugg et al., 1988, for similar interpretations). Which properties of the sentence are represented and in what form is a matter for further investigation. The point here is to assume that a trace that contains information related to the sentence exists, so that it is easier to integrate a new word into a previously digested context (same context/different word condition) than to integrate a word, even if it is repeated, into a wholly new context (different context/same word condition). Although the concept of integration may intuitively seem sound, it is not clear, for the moment, what is involved in integrating a word within a sentence context or what it means to say that integration is easy or difficult.

Finally, it is possible that what we have taken to be a modulation of N400 amplitude is instead due to the overlap of a positive component. For the sake of argument, let us assume that the subjects not only recognized most of the sentence contexts repeated in the same context/different word condition but in so doing sometimes also remembered some of the final words from the first encounter. For these cases, the final new word actually presented would violate the specific expectancies that the subjects may have generated while reading these sentences for the second time. The realization of such mismatch with a specific prediction based on previous experience (rather than the disconfirmation of a semantic expectancy) may have elicited a late positive component that would overlap with the N400 and yield the observed reduction in the latter half of N400 in the same context/different word condition. Moreover, this mismatch may have been surprising, and insofar as surprising events tend to be better recalled than nonsurprising ones (Donchin, 1981), thereby explain the advantage in cued recall found for the same context/different word condition.

In summary, although word predictability seems to account for the modulations in N400 amplitude between 200 and 400 ms, several interpretations in terms of residual activation, ease of integration, or mismatch with specific expectancies may account for the differences observed between 400 and 675 ms. Other experiments are clearly needed to differentiate among these.

Contribution of Word Meaning to the Word Repetition Effect

Our rationale for using ambiguous words in the present experiment was to determine the extent to which repetition of a word's meaning as opposed to its graphemic or phonemic forms is crucial for yielding repetition effects. Homographs were repeated at the end of new sentence frames that biased either the same meaning as on initial presentation or an alternative meaning. The results showed no difference in either the percentage of correct endings recalled or in the amplitude of the N400 in these two conditions: Insofar as the context was different from first presentation, it made no difference whether the biased meaning was same or different.

Related cued-recall results have been reported. For example, both Bobrow (1970) and Thios (1972) repeated homographs embedded in different sentence context conditions: (a) same sentence context (e.g., "The dog's bark frightened the baseball pitcher"), (b) similar sentence context (e.g., "The animal's bark scared the big league pitcher"), or (c) different sentence context that biased an alternative meaning of the homograph (e.g., "The medicinal bark filled the porcelain pitcher"). Results showed that cued recall of the second word of a pair on presentation of the first (i.e., *bark–pitcher*) was better when the same meaning of the homograph was biased on both encounters with the words, provided that the lag between repetitions was long (at least 16 words). These results could be taken as evidence that a word's meaning influences repetition priming. However, in both experiments, repetition of the homograph's meaning was confounded with context similarity. Word pairs with the same meaning were repeated in similar sentence contexts, whereas word pairs with different meanings were repeated in different contexts. When this confounding is avoided, as in the present experiment, repetition of a word's meaning does not seem to facilitate cued-recall performance.

Finally, note that the ERP data show a hint of an orthographic–phonemic repetition effect, whereas the cued-recall data do not. At midline central and parietal sites, the N400 is smaller in the different context/same meaning and different context/different meaning conditions than on initial presentation. If this effect is replicable, it suggests that repetition of graphemic–phonemic characteristics may contribute to the ERP repetition priming, even at long lags. Evidence for orthographic priming at long lags in the literature is mixed, with some authors observing it (e.g., Forster, 1987) while others do not (e.g., Feldman & Moskovljevic, 1987). If real, the present result would be an important demonstration of the sensitivity of the ERPs to processes that do not influence cued-recall performance.

Repetition Effects and Memory-Related Differences (Dm)

Previous experiments have shown that words subsequently remembered are associated with larger positivities than words subsequently not remembered (Fabiani et al., 1990; Karis et al., 1984; Neville et al., 1986; Paller, 1990; Paller, Kutas, & Mayes, 1987). What this enhanced positivity reflects is not yet clear, however. Donchin and his colleagues view the Dm as modulation of the P3 component, which they equate to a *context updating* process (Donchin, 1981; Donchin & Coles, 1988; Fabiani et al., 1990; Karis et al., 1984). On this view, surprising events are better recalled than not-surprising events because they necessitate updating of the mental representations to be integrated within the context in which they occur. Although language comprehension may always require context updating, one would expect Dm to be larger for incongruous than for congruous words. Because this is not the case (see next paragraph—Neville et al., 1986; Kutas, 1988), it is not clear how the context updating hypothesis accounts for results found in language experiments.

Neville et al. (1986), on the other hand, suggested that the enhanced positivity reflected more elaboration—a process known to increase recognition performance (Craik & Tulving, 1975). They found a Dm effect for both congruous and incongruous words, although for incongruous words the effect was delayed past the N400 peak. Similar results were reported by Kutas (1988) using a cued-recall memory test. These results differ from the present ones in that we found a significant memory-related effect in the N400 latency range (300–600 ms) for words on initial presentation. The materials that were used in these different experiments may account for the discrepancy: whereas both congruous and incongruous words were presented in the Neville et al. and Kutas experiments, only congruous words with low cloze probabilities were used in the present experiment.

In an attempt to track the functional significance of the Dm effect, the present experiment was specifically designed to determine the extent to which the ERP repetition effect and the memory-related differences reflect independent or interactive processes. According to additive-factors logic (Sternberg, 1969), an interaction between repetition and memory effects would imply that a common process underlies these effects. Results clearly show the following: (a) Dm was modulated by the various repetition conditions in the N400 latency band.[7] (b) Such a modulation was found only for words that were recalled; words that were not recalled did not show a hint of modulatory effects caused by the repetition conditions. (c) The scalp distribution of the repetition and memory effects was similar in the 300–600-ms range; both were

[7] For the nonhomographs, the positivity associated with words later recalled was larger in the exact repetition condition than in both the different context/same word and the different context/different word conditions but was not different from the same context/different word condition. For the homographs, the positivity associated with later recall was larger in the exact repetition condition than in either the different context/same meaning or the different context/different meaning conditions.

larger over centro-parietal and posterior temporal sites than at anterior temporal sites. We take these results as strong evidence that, between 300 and 600 ms, postterminal sentence word onset, repetition, and cued recall are subserved by similar processes or operations. Because cued recall is clearly an episodic memory test, the finding of an interaction between repetition and memory effects again points to the contribution of episodic memory to the word repetition effect. Furthermore, insofar as conscious recollection is part of the processes leading to successful cued recall, the fact that the only words later recalled were sensitive to the repetition conditions further suggests that for the kind of long-term repetition effects described here to occur, repetition has to be consciously noticed.[8] Such a conclusion is in line with the results reported by Oliphant (1983) that show no repetition effect for words initially embedded in the experimental instructions that subjects read aloud at the beginning of the experiment. Murray (1978) also showed that to-be-remembered four-letter items did not benefit from repetition in a distracting task.

The results reported here also have strong methodological implications: One should take into account the distinction between words later recalled and not recalled when studying word repetition effects. If this memory factor is ignored, then one could erroneously conclude some factor had no effect on word repetition simply because the words were processed in such a way as not to be later recalled. A study by MacLeod (1989) provides a good illustration of this point. He found that repetition priming in fragment completion was greater for isolated words presented in a to-be-learned list for later recall than for sensitive words presented in short passages. Furthermore, intermediate priming was obtained for incongruous words that were to be crossed out from the short passages. From these results, MacLeod (1989) suggested that "there is a gradient of priming as a function of prior context" (p. 403). Although recall performance was not reported either for isolated words or for words in text, our results suggest that the differential repetition priming effects reported by MacLeod may very well reflect the fact that words in the to-be-learned lists were better recalled than words that were specifically attended to (incongruous words to be crossed out), which were in turn better recalled than sensitive words for which no specific response was required. Of course, one central question for further research concerns the nature and characteristics of the processing of words that either do or do not render them later accessible for successful recall.

Although the present results do not yield any definitive answer, they provide two interesting clues that should be followed up. First, although neither the repetition effects nor the Repetition × Memory interaction were significant in the later latency band (600–1,200 ms), the Dm effect was still significant. Consequently, whatever the processes responsible for successful cued recall are, they cannot be equated with the processes that subserve repetition effects because they are reflected in a segment of the ERPs that is unaffected by repetition. In other words, while the repetition effects found in the present experiment may be explained by mechanisms similar to those that underlie the memory effects, other processes seem to be specific to successful retrieval. A tentative interpretation is that the later portion of the Dm effect reflects the elaboration of the appropriate episodic memory trace for subsequent retrieval.

Second, these results also shed light on the question of whether the process subserving successful cued recall is better described as continuous or all-or-none. The following argument is based on the assumption that Dm is correlated with the engagement of a process that leads to better conscious recollection. If this process is all-or-none, then the ERPs for words to be remembered should reflect engagement of this process, and ERPs for words that will not be remembered should not. Moreover, the difference between these ERPs, namely the Dm, should be invariant in the face of varying repetition contexts. Insofar as the amplitude of the Dm is not invariant but rather varies across the different repetition conditions, we would conclude that the memory-related process is continuous. The present results show that between 300 and 600 ms, the amplitude of the Dm effect differs as a function of repetition condition, being largest in the exact repetition (same context/same word) condition, smallest in the conditions in which the sentence contexts differ from initial presentation (different context/same word and different context/different word), and of intermediate amplitude in the same context/different word condition. Therefore, the present results provide evidence in favor of a continuous process subserving cued-recall performance.

In summary, two important findings emerge from the memory data. First, a common process seems to underlie the ERP repetition effects and the early part of the Dm effect in cued-recall memory test. This again points to the influence of episodic factors on the word repetition effect. Second, the later part of the Dm effect seems to reflect the engagement of a process specific to memory that would subserve successful cued recall. This process should be seen as a continuous one rather than as an all-or-none.

Conclusion

Our results for both nonhomograph and homograph words demonstrate that context has a significant impact on the word repetition effect. One question that might be raised is the extent to which these effects of context are specifically due to our use of a cued-recall memory test. It would be interesting to know, for instance, if a similar pattern of results would be obtained with no cued-recall memory tests intervening between first and second sentence presentation or with a cued-recognition test instead of a cued-recall test. In our previous studies (Besson, Kutas, & Van Petten, 1992), the cued-recall memory test was not always expected. Although

[8] In contrast, results of a number of experiments have demonstrated repetition priming effects in the absence of conscious recollection both in normal subjects and in amnesic patients (see Richardson-Klavehn & Bjork, 1988, for a review). It may be that the nature of the repetition priming effects differs between our experiments and these others or that variation in the amplitude of the N400 component only reflects the episodic source of repetition priming.

some minor differences were found in cued-recall performance, the overall pattern of ERP results was similar nonetheless. Therefore, it does not seem likely that retrieval strategies can explain the pattern of results reported here. Nevertheless, it remains possible that word repetition in a design with different task demands would have led to a smaller role for context. A recent study by Masson and Freedman (1990) bears on this issue.

These authors obtained results similar to ours by using a very different task, namely lexical decision (LDT; Masson & Freedman, 1990, Experiment 2). Homographs were repeated following (a) the same context word as seen on first presentation (e.g., MUSIC–ORGAN), (b) a different context word that biased either the same meaning (e.g., PIANO–ORGAN) or (c) an alternative meaning of the homograph (e.g., TRANSPLANT–ORGAN). Lexical decision times were faster in the identical repetition condition (492 ms) than in the other two conditions (558 ms and 590 ms, respectively). Therefore, these results, in combination with those of den Heyer (1986) and Carroll and Kirsner (1982), demonstrate that the large influence of context on word repetition is not restricted to cued recall but is also obtained in LDT and recognition memory tasks. Consequently, the pattern of results found in the present experiment cannot be attributed in its entirety to the episodic nature of the cued-recall memory test.

Note that while Masson and Freedman (1990) found that repeating a context word is more beneficial than changing the context word, unlike the present data, they also found that lexical decision times were faster when the new context word biased the same meaning than an alternative meaning of the homographs. However, this effect was tightly linked with the task. When a naming task was used (Masson & Freedman, 1990, Experiments 5 and 5a), pronounciation latencies did not differ for the same (547 ms) versus the different meaning condition (545 ms). Thus, results in the naming task were similar to those we obtained with the N400 measure and for cued recall and were different from those obtained in the LDT. Unfortunately, it was not possible to compare the effect of context (same vs. new context word) in the naming task used by Masson and Freedman (1990) and in the cued-recall memory test used here, because there was no identical repetition condition in the naming task. Additional experiments are needed to determine under what conditions meaning influences repetition priming and under what conditions it does not, as well as how these factors interact with the measure from which repetition priming is inferred.

In showing the large role of context on the word repetition effect, our results contrast with others that seem, at first glance, to emphasize the contribution of lexical memory instead. For instance, Rugg and Nagy (1987) reasoned that insofar as legal nonwords present wordlike characteristics, they should induce greater activation within lexical memory than illegal nonwords. Any difference between legal and illegal nonwords would thus be taken to reflect the contribution of lexical memory to the repetition effect. These authors did indeed find larger ERP repetition effects for legal than for illegal nonwords. Two caveats are in order, however. First, although smaller and more restricted, illegal nonwords produced a reliable repetition effect in the ERP (Experiment 1), implicating a role for episodic memory traces in the repetition effect. Second, Rugg and Nagy investigated immediate repetition, and the short-lived component of repetition priming may be responsible for the effects observed (Bentin & Moscovitch, 1988; Monsell, 1985; Ratcliff et al., 1985).

It is important to note that the effects of lag on the ERP repetition effects in word lists are not yet clear. Whereas some authors have reported these effects to be larger for immediate than delayed repetition (Bentin & Peled, 1990, for recognition memory task; Karayanidis et al., 1991), others have found no difference caused by lag (Bentin & Peled, 1990, for lexical decision task; Nagy & Rugg, 1989). In one study, it was found that the repetition effect on N400 amplitude was not significant when word repetition occurred in different word lists separated by at least 144 items (Fischler, Boaz, McGovern, & Ransdell, 1987). It would be important to vary word repetition lag in sentence experiments so as to determine how much of the difference between word and sentence repetition experiments can be accounted for by lag.

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