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Modulation of event-related brain potentials by word repetition: Effects of local context

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Abstract

In four experiments, event-related brain potentials (ERPs) were evoked by visually presented word pairs in a task requiring responses to occasional target pairs. In Experiments 1 and 2, some pairs comprised items that had been presented previously. These repeated pairs consisted of words that had been paired together when first presented (same context condition) or words that had first been presented on consecutive trials (different context condition). ERP repetition effects were equivalent in the two conditions. In Experiment 3, same-context repeats were contrasted with a condition in which a repeated word was paired with a new word. Only the same-context pairs evoked a repetition effect. Experiment 4 showed that repetition effects to different- and same-context repeats remained equivalent when first presentations of the members of different-context pairs were separated by six intervening trials. We conclude that the ERP repetition effect shows little sensitivity to local context.

Descriptors: Context, ERPs, Memory, Priming, Repetition effect

In tasks such as lexical decision and semantic classification, event-related brain potentials (ERPs) differ according to whether the words evoking them are being presented for the first or the second time (Bentin & Peled, 1990; Karayanidis, Andrews, Ward, & McConaghy, 1991; Nagy & Rugg, 1989; Rugg, 1985, 1987, 1990; Rugg, Furda, & Lorist, 1988). The ERP repetition effect takes the form of a widely distributed positive-going shift in the ERPs for repeated items, relative to the ERPs evoked by first presentations. The effect begins at around 250–300 ms poststimulus and continues for approximately a further 300 ms. A similar effect has also been observed when words are repeated in continuous text (Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991).

The functional significance of the ERP repetition effect is uncertain. There are reasons for supposing that it does not reflect the processes that mediate the heavily investigated phenomenon of repetition priming—the facilitation of task performance that occurs as a consequence of item repetition (see Richardson-Klavehn & Bjork, 1988, for a review). Not least among these reasons is that although repetition priming effects on isolated words persist over substantial periods of time (e.g., Scarborough, Cortese, & Scarborough, 1977) ERP repetition effects evoked by such items appear to dissipate over less than 15 min (Rugg, 1990).

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The number of ERP components contributing to the effect is also uncertain. Rugg (1990; see Young & Rugg, 1992, for a replication and extension) studied the effects of repeating high- and low-frequency words. He found that repeated high-frequency words modulated a temporally limited region of the ERP waveform, which centered on a negative-going component that peaked around 400 ms poststimulus. By contrast, the effects of repeating low-frequency words were more extended in time and seemed to involve the modulation not only of the negative deflection but also of a subsequent late positive component. Rugg (1990) argued that the ERP repetition effect, at least when evoked by low-frequency words, involves changes in amplitude of two temporally overlapping ERP components; a negative-going wave that is attenuated by repetition and a subsequent positive-going wave that is enhanced. Van Petten et al. (1991) and Besson, Kutas, and Van Petten (1992) arrived at similar conclusions about the component structure of the effect.

Rugg and Doyle (1994) argued that the earlier of the two components underlying the ERP repetition effect for isolated words could be identified with the intensively researched N400 component (see Rugg, 1990, for an abbreviated version of the same argument) (see Kutas & Van Petten, 1988, and Fischler & Raney, 1991, for reviews). They argued that an important factor controlling the amplitude of N400 is the ease with which attributes of the evoking stimulus can be integrated or associated with the context in which it is presented (see Halgren & Smith, 1987, for a similar view and Craik, 1989, for a general discussion of the role of contextual integration in memory). Thus, in the now classical paradigm used to modulate the N400—terminating a sentence with unpredictable, semantically incongruent versus predictable semantically congruent words (Kutas & Hillyard, 1980)—the larger N400 evoked by incongruent endings is held to reflect the greater difficulty of integrating such items with the context provided by the preceding items. Rugg and Doyle (1994; see also Holcomb, 1993) argued that a similar account could be given for the sensitivity of N400 to semantic priming manipulations with isolated words (e.g., Bentin, McCarthy, & Wood, 1985; Rugg, 1985), namely, that words are easier to integrate with a preceding context that includes a semantic associate (doctor → NURSE) then with one that includes an unrelated item (lecture → NURSE) (de Groot, 1985).

Rugg and Doyle (1994; see also Rugg, 1990, and Rugg et al., 1988) suggested that like sentential and semantic priming, repetition also can modify the ease with which an item can be integrated or assimilated with its context. They proposed that contextual integration is facilitated when an item recurs in the same context, leading to a smaller N400 component and a more positive-going ERP. Evidence in favor of this hypothesis comes from two studies of the effects of repeating words forming the terminal items of short sentences (Besson & Kutas, 1993; Besson et al., 1992). Besson et al. (1992) found that the repetition of sentences with predictable, congruent endings had very little effect on the ERPs evoked by their terminal words, whereas the sizeable N400 component evoked by terminal words of incongruent sentences was markedly attenuated on repetition. In a further study, Besson and Kutas (1993) employed sentences with congruous but unpredictable terminal words (such words, although forming meaningful sentences, nonetheless evoke sizeable N400s; Kutas & Hillyard, 1984). They found that the attenuation of N400 caused by the repetition of the terminal words was context dependent; no repetition effect was observed when the same word was used to terminate two different sentences, and repetition of a preceding sentence fragment had only a small (though reliable) effect on the amplitude of the N400 evoked by a new terminal word.

Within the framework of Rugg and Doyle (1994), the finding that the ERPs evoked by predictable, congruent terminal words are relatively insensitive to repetition reflects the fact that such words are easy to integrate with their preceding context when presented for the first time, and hence evoke little or no N400 activity even before repetition. By contrast, unpredictable terminal words are difficult to integrate when the sentences are first presented. Repetition of such sentences reinstates the context in which the terminal word was first processed. This reinstatement facilitates the integration of the word relative to the first time the sentence was presented, and the amplitude of the N400 evoked by the word diminishes accordingly. When a word is repeated in a new context, integration must begin anew, and the N400 resembles that evoked by unrepeated words.

Rugg and Doyle's (1994) contextual integration hypothesis can arguably account quite well for the interactive effects of sentence context and repetition on the N400 component. However, it is also intended to account for the effects of repetition (or, more accurately, that part of the ERP repetition effect attributable to N400) on ERPs evoked by words presented as isolated items in tasks such as lexical decision (e.g., Rugg, 1987) and for the sizeable ERP repetition effects that can be evoked by pronounceable nonwords (Rugg, 1987; Rugg & Nagy, 1987) and pictures (Rugg & Doyle, 1994). For the hypothesis to be viable therefore, the context with which an item is integrated must include a much broader constellation of variables than those provided by prior linguistic processing. Whenever an ERP repetition effect is found, these contextual variables must be assumed to have remained unchanged during the interval between first and second presentations.

The present experiments were part of an attempt to extend the contextual integration hypothesis beyond the effects of word repetition in sentence contexts by bringing the context in which isolated items are processed under experimental control. This control was achieved by requiring subjects to process two items on every experimental trial, so that each would serve as part of the context of the processing of its mate. The influence of context could then be investigated by comparing the consequences of repeating, on a subsequent trial, two items that had also been encountered together when first presented, as opposed to two items that had initially been encountered on different trials. If the ERP repetition effect reflects the beneficial consequences of reprocessing an item within the same context, it should be larger when items recur in the same pairing as on their first presentations than when items are paired with different words on their first and second presentations. This design is loosely based on those employed previously to investigate context effects in direct and indirect tests of memory (e.g., Carroll & Kirsner, 1982; Graf & Schacter, 1985; Masson & Freedman, 1990; McKoon & Ratcliff, 1979; Schacter & Graf, 1986). Graf and Schacter (1985) pointed out that such manipulations affect a word's local context, rather than the global context provided by the general experimental environment. Nothing in Rugg and Doyle's (1994) contextual integration hypothesis precludes the prediction that manipulations of local context should influence the ERP repetition effect. Because sentence fragments are regarded as contributing to local rather than global context, the findings of Besson et al. (1992) and Besson and Kutas (1993) suggest that manipulations of local context should exert a strong influence over the effect.

Experiment 1

This experiment addressed the issues discussed above by employing an adaptation of the lexical decision task used in several previous studies of the ERP repetition effect (Bentin & Peled, 1990; Nagy & Rugg, 1989; Rugg, 1987, 1990). In this task, subjects are required to respond promptly to the occurrence of nonword targets but to withhold responses to words. The task permits the recording of ERPs for critical items (first and second presentations of words) that, although subjected to an implicit lexical decision, do not demand an overt response. This minimizes the potentially confounding contribution of response-related components to the ERP waveforms of most experimental interest. In the present experiment, the procedure was modified so that two items were presented on each trial. In the majority of the trials, both items were words. Only in the occasional trials in which one of the items was a nonword was a response required.

Method

Subjects. The subjects were 12 young adults (7 women, 5 men, all right handed), who were paid £2/hr.

Stimuli. The stimuli were 565 open class words (mean [*SD*] length = 5.9 [1.1] letters; mean [*SD*] frequency of occurrence in the Francis & Kucera [1982] word count = 2.5 [2.4] per million) and 100 pronounceable nonwords (mean [*SD*] length = 5.9 [1.1] letters). One hundred of the words were randomly selected to be paired with nonwords; 65 of these occurred for the first time in the experiment with a nonword, and the remainder were presented twice, once with a filler item and subsequently with a nonword. A further 165 words were randomly selected to complete the filler pairs.

The remaining 300 words were employed to form the two repeat conditions. They were first randomly sorted into pairs, subject to the constraint that each member of the pair was of the same length, and then randomly assigned to one of three groups of 50 pairs. The items in one of these groups were used in the uncrossed repeat condition, in which the original pairing of items was retained in the repeat. The items in the other two groups supplied items to be used in the crossed repeat condition. In this condition, the repeating words were items that had first been paired with other nonrepeating words, as illustrated in Table 1. These three groups of word pairs were used to form a total of three lists, each with the same pseudorandom ordering of conditions. Across the lists, each group was employed once in the uncrossed condition and twice in the crossed condition. Each list was then rearranged to form a further three lists with a different ordering of items and conditions. A practice list consisting of 20 items, none of which appeared in the experimental lists, was also constructed.

The sequences were arranged so that the two word pairs containing items that were to be combined as a crossed repeat always occurred consecutively (Table 1). These were followed by a single filler pair, after which one (randomly selected) word from each of the critical pairs was presented as a crossed repeat. Thus, the mean lag between the first and second presentations of repeating words in the crossed repeat condition was 1.5 items. To produce the same mean lag in the uncrossed condition, half of the uncrossed repeats occurred after one intervening filler pair and half occurred after two intervening pairs. Word/nonword pairs in which the word was a repeat of a previously presented item were separated from the first presentation of the item by one to five intervening pairs of items.

All repeating items were presented in the same spatial position (above or below fixation) as on their first presentations. The spatial position of the nonwords was randomly determined, with the constraint that half should be above and half below fixation.

Stimulus pairs were displayed on a TV monitor for 300 ms. The fixation point was the center of an "X" created using forward and backward slash characters on the two lines that the item pairs were to occupy. The point of fixation was just to the right of the third letter of the items and halfway between the two lines of text. The upper edge of the lower item and the lower edge of the upper item were separated by approximately 0.7 degrees. The pairs subtended a vertical visual angle of approximately 0.7 degrees and a maximum horizontal angle of 2.0 degrees. The fixation point remained present other than for a period beginning 100 ms before stimulus onset until 1 s thereafter. The interstimulus interval was 3.2 s.

Table 1. *Experimental Designs and Examples of Materials Employed in Experiments 1–4*

Experiment	First presentation	Repeat	Condition
Targets			
1	*satan* *crust*	*satan* *ulder*	target/repeat
	bredle *hangar*		target/no repeat
2–4	*germ* *parson*	*germ* *bacteria*	target/repeat
	coroner *inquest*		target/no repeat
Repetition conditions			
1–4	*ounce* *chess*	*ounce* *chess*	uncrossed
1, 2, 4	*cartoon perjury* *nausea pelvis*	*cartoon* *pelvis*	crossed[a]
3, 4	*gender* *snout*	*gender* *spine*	partial

[a]First presentations of crossed repeats were made on consecutive trials in Experiments 1 and 2 but were separated by six intervening trials in Experiment 4.

Procedure. Subjects were seated in front of the TV monitor with the right index finger resting on a microswitch pushbutton. They were informed that they would see pairs of letter strings appear on the screen and that their task was to read both the strings and to respond promptly if one of them was a nonword. They were told that they would occasionally see items that had appeared before, that this was part of the experimental procedure, but that they should merely concentrate on responding to nonwords as rapidly and as accurately as they could. They were further instructed to move as little as possible, to maintain fixation, and to avoid blinking when the fixation asterisk was absent from the monitor.

Following the practice trials, the subjects performed the task with one of the six experimental lists. The experimental run was broken into five blocks of 90 trials each, with a brief rest period between each block.

ERP recording. The electroencephalogram (EEG) was recorded from silver/silver chloride electrodes from nine scalp sites, each referenced to linked mastoids. Three midline sites were employed (Fz, Cz, and Pz, according to the international 10-20 system of Jasper, 1958), and there were three pairs of lateral electrodes situated over left and right frontal (midway from F3 to F7 on the left and from F4 to F8 on the right), temporal (midway from C3 to T3 and from C4 to T4), and parietal (midway from P3 to T5 and from P4 to T6) regions. Eye movements were monitored with a bipolar electrode pair situated on the outer canthus of the left eye and the supraorbital ridge of the right eye. All channels were recorded with a band width of 0.03–30 Hz (3 dB points) and sampled on-line at a rate of 4 ms/point. Sampling began 100 ms before stimulus onset and continued for 1,024 ms. ERPs were formed for each experimental condition by averaging error-free trials during which the amplitude of the electrooculogram (EOG) channel remained within a preset criterion. The EOG was averaged along with the EEG to ensure that the rejection of eye movement artifact was successful.

Results

Behavioral data. Mean RTs, correct detections, and false positive responses are shown in Table 2. The RTs for targets paired with a repeating item did not differ significantly from RTs for targets paired with a new word. The proportion of cor-

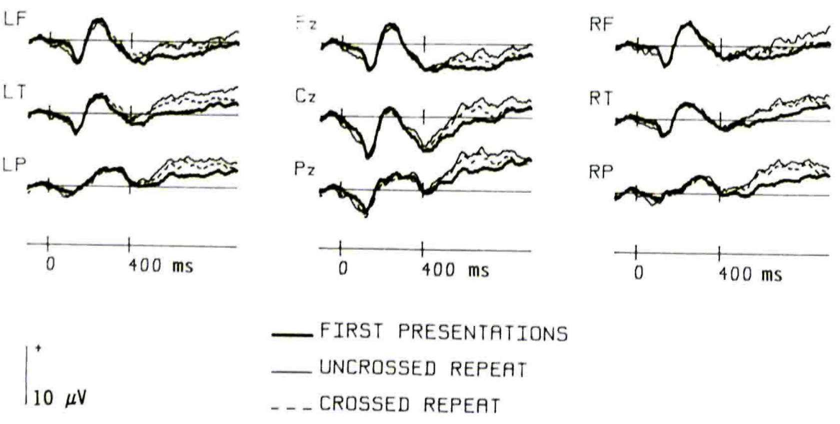

Figure 1. Grand average ERPs from Experiment 1 evoked by word pairs on their first presentations and by pairs containing uncrossed and crossed repeats. Fz, Cz, and Pz signify frontal, central, and parietal midline electrodes. LF, RF, LT, RT, LP, and RP signify left and right frontal, temporal, and parietal electrodes, respectively.

rect detections was however higher for nonwords paired with repeats ($F[1,11] = 26.70$, $p < .001$). The proportions of false positive responses associated with first presentations and uncrossed and crossed repeats were subjected to an analysis of variance (ANOVA), which revealed a significant main effect ($F[2,22] = 13.81$, $p = .001$, $\epsilon = 0.731$). A Newman–Keuls test revealed that the false positive rates associated with both repeat conditions were lower than the rate associated with first presentations.

ERPs. Preliminary analyses were conducted to search for differences between (a) the ERPs evoked by the first presentations of word pairs subsequently repeated in the uncrossed versus the crossed conditions and (b) ERPs evoked by uncrossed repeats occurring after a lag of one versus two intervening trials. These analyses revealed no evidence of any such differences. Thus, each subject's waveforms were collapsed to yield three sets of ERPs, those evoked by first presentations and by uncrossed and crossed repeats. The grand averages of these ERPs are illustrated in Figure 1. Effects of repetition emerged approximately 450–500 ms poststimulus in the form of a sustained positive-going shift. The effects were widespread over the scalp and showed little sign of differentiating uncrossed and crossed conditions until relatively late in the recording epoch, when they appear to decline more rapidly in the crossed condition, especially over the midline.

The ERPs were quantified by measuring the mean amplitude of sequential 100-ms latency regions. Each of these data sets was initially subjected to two ANOVAs, one for the data from the midline electrodes and one for the lateral data. The ANOVAs of the midline data included the variables of condition (first presentation vs. crossed repeat vs. uncrossed repeat) and electrode site. Those for the lateral data included the additional variable of hemisphere. The degrees of freedom of all F ratios for factors with more than two levels were adjusted with the Greenhouse–Geisser procedure to correct for nonsphericity. Those ANOVAs that yielded significant condition main effects or interaction effects involving condition were followed by separate analyses that, using error terms specific to each comparison, contrasted the two repeat conditions with one another and each repeat condition with the first presentations.[1]

The outcomes of these ANOVAs and their associated subsidiary analyses are shown in Table 3. In no case did the condition effect interact with either electrode site or hemisphere, and thus the table gives information solely about condition main effects. Such effects first attain significance in the 400–500-ms latency region and are then present throughout the remainder of the recording epoch. The ERPs evoked by the uncrossed repeats remain significantly more positive-going than first presentations, at both midline and lateral electrodes, for all latency regions later than 400 ms. The waveforms associated with the crossed repeats do not differ reliably from first presentations until the 500–600-ms latency region, and these differences begin to dissipate in the 700–800-ms region, the only region other than that between 400 and 500 ms in which the two repeat conditions differ significantly from one another.

Table 2. *Experiment 1 Behavioral Data*

Targets				Nontargets (% false positive)[a]		
With repeat		Without repeat				
RT (ms)	% Correct	RT (ms)	% Correct	1st	U	C
1,036	78.3	1,054	67.5	18.2	9.3	8.5

[a] 1st = first presentation; U = uncrossed repeats; C = crossed repeats.

Discussion

These data offer only weak support for the hypothesis that contextual factors influence the size of the ERP repetition effect. The crossed condition gave rise to a reliable positive-going ERP modulation that, for much of its duration, was statistically indis-

[1] The analytic approach adopted for this and the subsequent experiments was deliberately liberal. The aim was to maximize the chances of finding evidence that changes in local context influence the ERP repetition effect. In view of the liberal nature of these analyses, the absence of such evidence in Experiments 1, 2, and 4 seems unlikely to reflect Type II error.

Table 3. *Experiment 1 Condition Effects for Overall ANOVA and Planned Subsidiary ANOVAs*

Latency region (ms)	Overall[a]			Subsidiary[b] U vs. 1st		C vs. 1st		U vs. C	
	F	ε	*p*	*F*	*p*	*F*	*p*	*F*	*p*
400–500									
Midline	3.92	0.767	.049	17.39	.002	1.65	.226	1.43	.258
Lateral	4.00	0.971	.035	7.80	.018	4.05	.070	0.24	.632
500–600									
Midline	10.07	0.699	.001	23.43	.001	17.49	.002	0.96	.345
Lateral	21.23	0.988	.000	34.73	.000	24.52	.000	2.10	.176
600–700									
Midline	14.03	0.891	.000	38.13	.000	12.84	.004	1.98	.187
Lateral	28.32	0.977	.000	62.85	.000	25.26	.000	4.01	.071
700–800									
Midline	8.22	0.789	.005	27.87	.000	2.29	.159	5.21	.043
Lateral	17.34	0.725	.000	53.72	.000	7.96	.017	6.76	.025
800–900									
Midline	3.96	0.930	.038	9.18	.011	0.78	.394	2.86	.120
Lateral	8.29	0.902	.003	19.33	.001	5.34	.041	2.96	.113

[a]Degrees of freedom are 2 and 22. [b]U = uncrossed repeats; 1st = first presentations; C = crossed repeats. Degrees of freedom are 1 and 11.

tinguishable from that evoked by the uncrossed repeats. The clearest evidence of a difference between the two conditions came toward the end of the recording epoch when, for one latency region only, the ERPs evoked by the crossed repeats were reliably less positive than those evoked by the uncrossed repeats.

The onset and offset latencies of the ERP repetition effect found in this experiment (and in the subsequent ones) were delayed by about 100 ms relative to those typically found when only single words are repeated (cf. Rugg et al., 1988). A similar delay was noted by Otten, Rugg, and Doyle (1993), who also studied the effects on ERPs of the repetition of vertically aligned word pairs. Otten et al. accounted for this delay by proposing that the presence of two rather than one item in the display imposed an additional perceptual processing load that required time to be overcome. A similar account seems equally applicable to the present data. By this account, the delayed repetition effects in ERPs evoked by word pairs does not constitute evidence that the components responsible for these effects differ from those underlying the effects evoked by single words. Rather, it is merely a reflection of the additional time needed to process two-item as opposed to one-item displays.

A possible reason for the weak contextual effects found in this study lies with the experimental task. This task was designed to ensure that subjects could only decide that a trial did not contain a target item by processing both of the words. But the task does not ensure that the word pairs are processed in any kind of relational fashion. On the contrary, it can be performed perfectly by attending first to one and then to the other member of each word pair. If words only become associated in memory when they are concurrently the focus of attention, a task (such as the present one) that encourages subjects to adopt an item-by-item strategy is unlikely to demonstrate powerful context effects. The results of Graf and Schacter (1985) and Schacter and Graf (1986) suggest that a member of a word pair acts as context for its mate most effectively when the meanings of the two words are processed relationally.

Experiment 2

A weakness of the lexical decision task employed in Experiment 1 is that it permits subjects to process the members of critical word pairs discretely, thereby minimizing the opportunity for the two items to be associated with one another. In the present experiment, this possibility was eliminated by employing as target trials semantically related word pairs. To withhold correctly a response on nontarget trials, it was necessary to identify each member of the word pair and to compare its meaning with that of its mate. Thus, this task ensures that the meanings of the members of critical item pairs are subjected to relational processing. If under these circumstances items form mutual contexts for one another, then according to the contextual integration hypothesis, uncrossed repeats will give rise to larger ERP repetition effects than will crossed repeats.

Method

Subjects. A second group of 12 young adults (9 women, 3 men) were recruited and paid £3/hr. Eleven subjects were right handed.

Stimuli. The stimuli were based on those employed in Experiment 1. In the present experiment, however, target trials were defined not by the presence of a nonword but by a pair of words that were semantically related (see Table 1). Thus the items from Experiment 1 were modified so that related word/word pairs could be substituted for the word/nonword pairs used in that experiment. It was not possible to construct 100 related pairs of low-frequency words where both words were the same length. The words making up the experimental pairs were therefore recombined into new pairings in which the relative lengths of the constituent words were, on average, the same as for the target pairs. As in Experiment 1, two sequences of experimental conditions were generated, and these were employed with the three groups of experimental items to produce six experimental lists. The stimuli were displayed in the same manner and with the same parameters as in Experiment 1. A practice list of 20 items was also constructed.

Procedure. Subjects were treated in the same general fashion and given the same instructions about eye and body movements as in Experiment 1. They were informed that they would see word pairs appearing on the monitor and that they were to read both of the words and decide whether they were related in meaning. If the words were related, subjects were to respond as rapidly as possible, and if the words were not, they were to refrain from making any response. After ensuring that the task was understood and that performance on the practice trials was satisfactory the experiment was run using one of the six experimental lists. Short rests were given after each block.

ERP recording. All aspects of ERP recording were as in Experiment 1, except that EEG was recorded using tin electrodes mounted in a proprietary electrode cap (Electro-Cap International, Dallas, TX, USA).

Results

Behavioral data. Mean RT, correct detections, and false positives are shown in Table 4. RTs were faster ($F[1,11] = 8.84$, $p < .05$) for target pairs in which one of the words was a repeat,

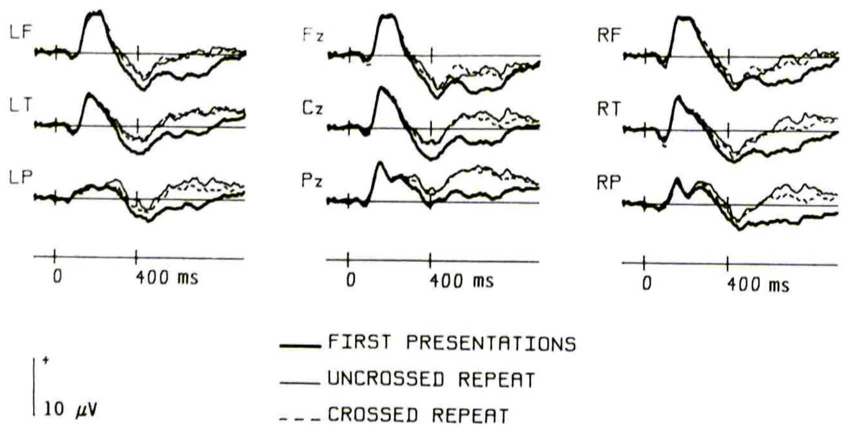

Figure 2. Grand average ERPs from Experiment 2 evoked by word pairs on their first presentations and by pairs containing uncrossed and crossed repeats. Electrode sites as in Figure 1.

but accuracy of responding to the two types of target did not differ significantly. An ANOVA of the false positive data gave rise to a significant effect ($F[2,22] = 5.53, p < .015, \epsilon = 0.927$). Post hoc analyses showed that the false positive rate for first presentations was higher than that for uncrossed repeats; the rate for crossed repeats differed from neither of the other two conditions.

ERPs. As in Experiment 1, preliminary analyses revealed no differences between lag 1 and lag 2 uncrossed repeats nor between the first presentations associated with the two repeat conditions. ERPs were therefore collapsed over these variables to give waveforms associated with first presentations and uncrossed and crossed repeats. The relevant grand averages are shown in Figure 2. Compared with those of first presentations, ERPs evoked by both kinds of repeat are more positive-going from around 300 ms poststimulus.[2] There is little evidence of any difference between the two repeat conditions until a latency of around 600 ms, when there is a tendency for the crossed repetition effect to decline at some electrode sites.

The ERPs were quantified and analyzed in the same fashion as in Experiment 1. As in that experiment, main effects of condition in the overall ANOVAs consistently failed to interact with any other variable. The results of these ANOVAs and the subsequent follow-up analyses are shown in Table 5. From 300 ms onward, the ERPs from the two repeat conditions are significantly more positive-going than those evoked by first presentations and do not differ significantly from one another.

Discussion

Far from enhancing the weak effects of context observed in Experiment 1, the task employed in this experiment abolished them altogether. Before accepting that the findings reflect a genuine insensitivity on the part of ERPs to the crossed/uncrossed manipulation, it is necessary to rule out a possible alternative. The apparent insensitivity of ERPs to uncrossed versus crossed repetitions could merely reflect the electrophysiological equivalent of a ceiling effect, whereby the presence of a single repeated item in a pair is sufficient to "saturate" the generator(s) of the repetition effect to such an extent that the waveforms are insensitive to any variable (such as the presence of a second repeated word) that could enhance it further. The next experiment was designed to rule out this possibility.

Experiment 3

The purpose of this experiment was to compare the effects of repeating both members of a previously presented word pair with the effects of repeating only one member of the pair. The task employed in Experiment 2 was modified so that the uncrossed repeat condition could be contrasted with a *partial* condition, in which an item that had been presented as a member of an earlier pair was subsequently paired with a word that was being presented in the experiment for the first time. If the repetition of a single member of a word pair is sufficient to produce an asymptotic ERP repetition effect, the effects of the uncrossed and partial repeats will be equivalent in magnitude. This result would suggest that the apparent insensitivity of ERPs to the uncrossed/crossed conditions of Experiments 1 and 2 is

[2] In this and subsequent experiments, the ERPs in the region of the N1 and P2 deflections are markedly less negative-going than those obtained in Experiment 1, especially over the midline. Two possible reasons for this difference are (a) the change in experimental task and (b) a change in the model of TV monitor employed to display the stimuli (National Panasonic WV-950 in Experiment 1, Commodore 1084s in Experiments 2–4). Because these waveform differences do not interact with any experimental manipulation, no attempt was made to ascertain which of these possibilities is correct.

Table 4. *Experiment 2 Behavioral Data*

Targets				Nontargets (% false positive)[a]		
With repeat		Without repeat				
RT (ms)	% Correct	RT (ms)	% Correct	1st	U	C
922	81.2	974	77.7	6.9	4.0	5.2

[a] 1st = first presentation; U = uncrossed repeats; C = crossed repeats.

Table 5. *Experiment 2 Condition Effects for Overall ANOVA and Planned Subsidiary ANOVAs*

Latency region (ms)	Overall[a]			Subsidiary[b] U vs. 1st		C vs. 1st		U vs. C	
	F	ε	*p*	*F*	*p*	*F*	*p*	*F*	*p*
300–400									
Midline	5.34	0.985	.013	8.58	.014	6.31	.029	0.47	.504
Lateral	5.07	0.882	.020	9.00	.012	6.71	.025	0.86	.373
400–500									
Midline	5.62	0.959	.012	7.39	.020	10.58	.008	0.00	.998
Lateral	4.35	0.802	.036	6.64	.026	10.82	.007	0.06	.816
500–600									
Midline	9.89	0.986	.001	12.50	.005	15.27	.002	0.25	.624
Lateral	8.46	0.967	.002	13.39	.004	14.42	.003	0.06	.810
600–700									
Midline	18.31	0.941	.000	25.58	.000	23.15	.001	0.64	.438
Lateral	18.01	0.991	.000	29.91	.000	20.61	.001	1.15	.307
700–800									
Midline	8.52	0.784	.004	30.92	.000	7.13	.022	1.24	.289
Lateral	13.78	0.866	.000	37.57	.000	13.87	.003	1.64	.227
800–900									
Midline	2.49	0.914	.112	5.52	.039	2.72	.128	0.35	.564
Lateral	9.75	0.882	.002	27.23	.000	9.79	.010	0.74	.405

[a]Degrees of freedom are 2 and 22. [b]U = uncrossed repeats; 1st = first presentation; C = crossed repeats. Degrees of freedom are 1 and 11.

indeed attributable to a ceiling effect arising from the repetition of a single item.

Method

Subjects. Twelve young adults (11 women, 1 man; 9 right handed) were recruited and remunerated as in the previous experiment.

Stimuli and procedure. The stimuli were drawn from the same set as employed in Experiment 2. The two critical conditions consisted of uncrossed repeats, when a word pair repeated after two intervening trials, and partial repeats, when one member of a word pair was repeated, along with a new word, after two intervening trials. Target stimuli were unchanged from Experiment 2. The design of the experiment is summarized in Table 1. One of the three groups of 50 pairs used as experimental items in the previous experiment were transferred to the pool of filler pairs, leaving two groups of 50 experimental items. A further 50 words, having similar characteristics to the experimental items, were chosen from the set of Francis and Kucera (1982). In the partial repeat condition, these items were used to replace one member of each word pair between first and second presentations. As in the previous experiments, two pseudorandom sequences of experimental conditions were constructed. Four experimental lists were produced by crossing the two condition sequences with the two groups of critical word pairs. A practice list of 20 items was also constructed.

The probability of occurrence of targets and of the two repeat conditions was the same as in Experiments 1 and 2. Display parameters, experimental procedure, and task instructions were identical to those of Experiment 2.

ERP recording. ERPs were recorded and formed as in Experiment 2.

Results

Behavioral data. RTs, correct detections, and false positives are summarized in Table 6. Target RTs were faster when one member of a target pair was a repeat than when both words were new ($F[1,11] = 33.36$, $p < .001$), but correct detection rates did not differ significantly. An ANOVA of false positive rates failed to achieve significance ($F[2,22] = 3.58$, $p < .08$, $\epsilon = 0.574$).[3]

ERPs. Preliminary analyses revealed no differences between first presentations of uncrossed and partial repeats, which were therefore pooled as in the previous experiments. Figure 3 illustrates the grand average ERPs from the three critical conditions. A repetition effect is evident in the uncrossed condition from around 500 ms poststimulus. By contrast, the partial condition appears to give rise to little or no effect.

The ERP waveforms were subjected to ANOVAs of consecutive 100-ms latency regions, adopting the same strategy as in Experiments 1 and 2. As in those experiments, in no region did the main effects of condition interact with any other factor. The results of this analysis are shown in Table 7. Condition effects first emerge in the overall ANOVA in the 500–600-ms latency region and are reliable for the remainder of the epoch. From 500 ms onward, uncrossed repetitions give rise to significantly more positive ERPs than do first presentations, whereas the partial repeats fail to evoke a reliable effect in any latency region. Further, the ERPs evoked by the uncrossed and partial repeats differ reliably for most of the recording epoch after 500 ms.

Discussion

The results of this experiment seem to rule out the possibility that the insensitivity of ERPs to the crossed/uncrossed manipulations seen in Experiments 1 and 2 came about because the repetition of a single item produced an asymptotic effect. On the contrary, the pairing of a previously presented item with one presented for the first time gave rise to no statistically significant repetition effect. This result cannot be attributed to a general insensitivity to the presence of a single repeated item. As was true also in Experiment 2, target pairs containing a repeated item were responded to more rapidly than were those containing two new words. Hence, a single repeated item in a word pair led to differential processing, but not of a form reflected in ERPs.

Experiment 4

The experiments described thus far show that ERPs evoked by word pairs demonstrate a repetition effect only when both members of the pair are repeated, and that the effect does not differ

[3]The nonsignificant difference in false alarm rate between first presentations and uncrossed repetitions may seem anomalous, given that the size of the difference, 5.6%, is greater than the significant 2.9% difference found in Experiment 1. These disparate findings arise because the across-subject standard deviation in false alarm rate for first presentations in Experiment 3 was twice that of Experiment 2 (9.1 vs. 4.6). We have no ready explanation for this difference in variance, which was not apparent in false alarm rates for either uncrossed (3.4 vs. 4.8) or crossed (3.9 vs. 4.2) repeats.

Table 6. *Experiment 3 Behavioral Data*

Targets				Nontargets (% false positive)[a]		
With repeat		Without repeat				
RT (ms)	% Correct	RT (ms)	% Correct	1st	U	P
893	76.6	949	75.1	9.9	4.3	5.2

[a] 1st = first presentation; U = uncrossed repeats; P = partial repeats.

according to whether the words were originally paired together on the same trial or were displayed on successive trials.

What matters in these experiments may be whether both members of a repeated pair were processed initially within some critical interval. Perhaps the critical variable is not whether two items were presented on the same trial but whether they were represented concurrently within short-term or working memory, thereby allowing the formation of intertrial associations. Alternatively, the ERP repetition effect for word pairs may occur only if the first presentations of both items are still represented within short-term memory at the time of their (conjoint) repetition. Because the first presentations of items subsequently repeated as crossed pairs always occurred on consecutive trials, and the number of other items intervening between first and second presentations of either crossed or uncrossed pairs never exceeded four, both of these possibilities seem plausible.

In light of these possibilities, Experiment 4 was designed to ascertain whether the ERP repetition effect for crossed repetition was evident when the first presentations of the two items were separated by several trials. The experiment contrasted the effects evoked by the uncrossed and partial repetition conditions employed in the previous experiments with those obtained by a crossed repetition condition in which the first presentations of the repeated words were separated by six intervening trials. This intertrial lag corresponds to an interval of approximately 20 s and to the presentation of 12 different intervening items. This number of items far exceeds the capacity of short-term memory, at least as usually conceptualized (e.g., Baddeley, 1990). Hence, if crossed repetition under these conditions yields an ERP repetition effect, the hypothesis that such effects require that the first presentations of both items must be, or have been, concurrently represented in short-term memory can be rejected.

Method

Subjects. Eighteen young adults (3 women, 15 men; 10 right handed) were recruited and remunerated as in the previous experiments.

Stimuli and procedure. The same set of words was used as in Experiment 2. An additional 33 target pairs were produced that had similar semantic relations to those used in the previous two experiments. Two of the experimental conditions, uncrossed and partial repeats, were identical to those employed in Experiment 3. The third critical condition, involving crossed repetition, was the same as that employed in Experiments 1 and 2, with the exception that pairs containing items that were to be combined as a crossed repeat were separated by six intervening trials (see Table 1). The word pairs employed in these three critical experimental conditions were a subset of the three sets of 50 pairs used in Experiment 2. One hundred twenty-six of these pairs were split into three sets of 42 pairs. Each set was used once for each of the three conditions. As in the previous experiments, two pseudorandom sequences of experimental conditions were constructed. Six experimental lists were then produced by crossing the two condition sequences with the three groups of critical word pairs.

Subjects were presented with 665 trials split into seven blocks of 95 trials. Each block contained 18 repeats, 24 first presentations, 19 targets, and 34 fillers. A practice list of 15 items was also constructed. Display parameters, experimental procedure, and task instructions were identical to those of Experiments 2 and 3.

ERP recording. ERPs were recorded and formed as in Experiments 2 and 3.

Results

Behavioral data. RTs, correct detections, and false positives are summarized in Table 8. Responses to target pairs contain-

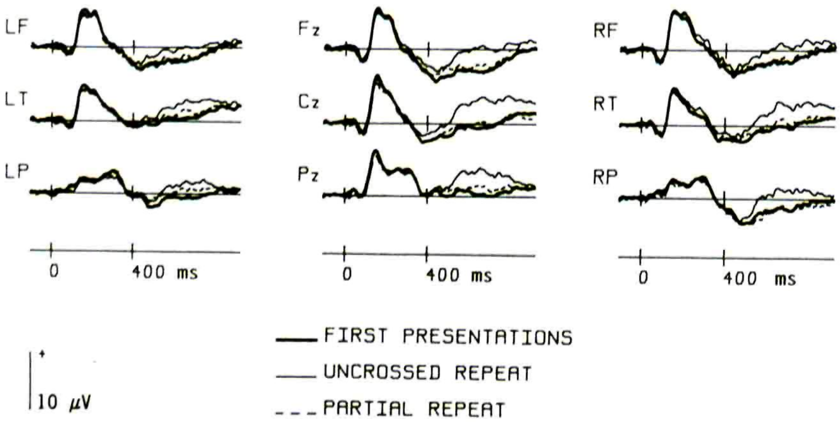

Figure 3. Grand average ERPs from Experiment 3 evoked by word pairs on their first presentations and by pairs containing uncrossed and partial repeats. Electrode sites as in Figure 1.

Table 7. *Experiment 3 Condition Effects for Overall ANOVA and Planned Subsidiary ANOVAs*

Latency region (ms)	Overall[a]			Subsidiary[b] U vs. 1st		P vs. 1st		U vs. P	
	F	ϵ	p	F	p	F	p	F	p
500–600									
Midline	5.74	0.832	.015	8.82	.013	0.88	.365	5.00	.047
Lateral	5.11	0.752	.026	7.97	.017	1.54	.242	3.75	.079
600–700									
Midline	17.74	0.881	.000	32.06	.000	2.91	.117	14.22	.003
Lateral	14.37	0.783	.000	24.56	.000	4.59	.056	9.80	.010
700–800									
Midline	12.40	0.841	.001	16.12	.002	1.37	.268	14.09	.003
Lateral	13.55	0.910	.000	20.44	.001	1.39	.264	13.72	.003
800–900									
Midline	4.03	0.886	.039	5.38	.041	0.27	.612	4.82	.051
Lateral	4.49	0.938	.026	8.28	.015	0.10	.753	4.72	.053

[a]Degrees of freedom are 2 and 22. [b]U = uncrossed repeats; 1st = first presentation; P = partial repeats. Degrees of freedom are 1 and 11.

ing a repeated word were faster ($F[1,17] = 42.64$, $p < .001$) and more accurate ($F[1,17] = 35.23$, $p < .001$) than for pairs containing an unrepeated word. False positive rates in the different nontarget conditions did not differ significantly.

ERPs. As in the preceding experiments, preliminary analyses indicated that it was appropriate to collapse ERPs to yield waveforms evoked by first presentations and uncrossed, crossed, and partial repeats. The grand averages of these waveforms are shown in Figure 4. Compared with first presentations, the crossed and uncrossed repeats evoked more positive-going waveforms from approximately 300 ms poststimulus onward. The size of this effect does not appear to differ between the two conditions. By contrast, ERPs for partial repeats closely resemble those evoked by first presentations.

As in the previous experiments, these data were analyzed by ANOVAs of the average amplitudes of consecutive 100-ms epochs. When an overall ANOVA gave rise to a significant effect involving condition, four planned subsidiary ANOVAs were then performed. Three of these ANOVAs contrasted measures from the crossed condition with those associated with first presentations, uncrossed repeats, and partial repeats, respectively. The first of these contrasts established whether the crossed condition evoked a significant repetition effect, the second whether the effect differs from that evoked by uncrossed repetition, and the third whether the effect is greater than that evoked by partial repeats. The final contrast, between partial repeats and first presentations, allowed the effects of partial repetition in this experiment to be compared with those in Experiment 3.

The outcome of these ANOVAs is shown in Table 9. Condition was never found to interact with site or hemisphere, and therefore the table summarizes main effects only. The crossed condition differs from first presentations from 300–400 ms until 700–800 ms, and from partial repeats from 300–400 ms until 600–700 ms. No contrast between crossed and uncrossed conditions or between partial repeats and first presentations approaches significance. This pattern of results indicates that the crossed repeats evoked ERP repetition effects equivalent in size to those evoked by uncrossed repeats and that these effects depended critically on the repetition of two words; as in Experiment 3, single word repetition had no detectable effect on ERPs.

Table 8. *Experiment 4 Behavioral Data*

Targets: With repeat RT (ms)	% Correct	Without repeat RT (ms)	% Correct	Nontargets (% false positive)[a] 1st	U	C	P
947	80.3	1,002	73.9	3.7	3.6	2.9	2.5

[a]1st = first presentation; U = uncrossed repeats; C = crossed repeats; P = partial repeats.

Discussion

The results of this experiment show that ERP repetition effects evoked by crossed repetition can be found when the first presentations of repeated items are separated by 12 intervening items. Under these conditions, crossed repetition yielded effects equivalent in size to those evoked by uncrossed repetition. Partial repetition once again failed to give rise to a significant ERP effect, showing that the effects observed with crossed and full repetition depend critically on repetition of both members of a pair.

The present findings indicate that crossed ERP repetition effects do not require that the two members of a repeated pair need ever have been represented concurrently in short-term memory. The findings therefore offer no support for the hypothesis that crossed ERP repetition effects occur when the first presentations of the members of crossed pairs are both represented in short-term memory at the time they are repeated.

The findings from the partial repetition condition of the present experiment were identical to those from the same condition of Experiment 3 and reiterate that the pairing of a repeated word with a word new to the experiment fails to yield an ERP repetition effect. It is of interest to compare this finding with the results of Otten et al. (1993). Otten et al. (1993) presented a word pair on each trial, one member of which was sometimes a repeat from the immediately preceding trial. Unlike in the present experiments, subjects were cued on a trial-by-trial basis to attend only to one member of the pair. In two experiments, words attended on both their first and second presentations gave rise to a large, reliable ERP repetition effect of approximately the same magnitude as the effects observed in the experiments here. Thus, the failure to find an ERP repetition effect for partial repeats may hold only when both members of a word pair are attended.

Why do partial repetitions fail to give rise to an ERP repetition effect? One possibility stems from the finding of Otten et al. (1993; see also McCarthy & Nobre, 1993) that robust ERP repetition effects are observed only when an item is attended on both its first and second presentation.[4] The absence of an ERP repetition effect for the combination of a repeated and a new

[4]We are grateful to an anonymous reviewer for suggesting this possibility.

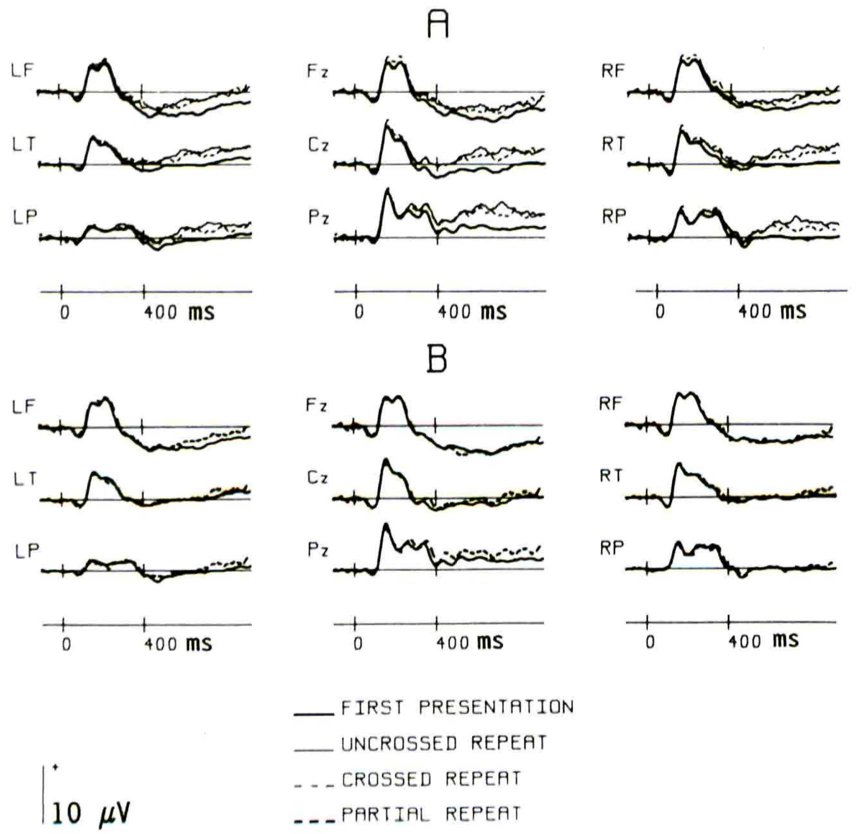

Figure 4. Grand average ERPs from Experiment 4 overlaying (A) waveforms evoked by first presentations and by crossed and uncrossed repeats and (B) waveforms evoked by first presentations and by partial repeats. Electrode sites as in Figure 1.

word could therefore reflect the lack of attention paid to repeated words when they must compete for attention with new items. Just such an attentional bias has been reported by Johnston, Hawley, Plewe, Elliot, and De Witt (1990) in a series of behavioral experiments. Johnston et al. found that localization accuracy for words in masked four-item arrays was poorer for items repeated from previous trials than it was for words new to the experiment, an effect they attributed to the tendency of the new items automatically to capture attention.

The marked differences in experimental design between the present studies and those of Johnston et al. (1990) make detailed comparisons between the two sets of findings impossible. Nonetheless, two of the properties of the *novel popout* effect described by Johnston et al. suggest that this effect does not underlie the absent ERP repetition effect for partial repetitions in Experiments 3 and 4. First, novel popout was not found for arrays consisting of equal proportions of repeated and novel words, the situation obtaining in the present experiments. Second, and more important, novel popout became reliable only after old words had been repeated well over 100 times, which is in marked contrast to the present experiments, in which items were repeated once only. In addition, the nature of the task employed in Experiments 3 and 4 makes it implausible to suppose that subjects directed attention solely to the new word. To reject correctly partial repetitions as targets, it was necessary to identify and compare the meanings of both words; the presence of repeated items among target pairs meant that the mere detection of repetition was not sufficient to permit partial repeats to be correctly categorized as nontargets. For these three reasons, the possibility that the absent ERP repetition effect for partial repetition is a result of attention capture by the new word seems unlikely.

General Discussion

When subjects process word pairs to make a double lexical decision (Experiment 1) or a semantic comparison (Experiments 2–4), ERPs are reliably modulated by the repetition of previously presented items but are largely insensitive to whether items are repeated in the same (uncrossed) or in a different (crossed) pairing, even when the first presentations of crossed repeats are separated by six intervening trials (Experiment 4) (Figure 5). But repetition of only one member of a previously presented pair (partial repeat, Experiments 3 and 4) has no reliable effect on ERPs, although such repetitions do facilitate responses to target pairs.

The initial motivation for these experiments was the hypothesis that the ERP repetition effect is, in large part, a consequence of repeating an item within the same context as that in which it was first presented (Rugg & Doyle, 1994). The finding that uncrossed and crossed repetition effects barely differ is difficult to reconcile with the hypothesis that spatially adjacent, simultaneously presented words are encoded together in memory in a form that permits them to serve as mutual contexts for one another. The results of Experiments 2 and 4 appear especially compelling in this respect, in that the experimental task ensured that the critical words were processed both semantically and relationally; a combination which promotes the formation of epi-

Table 9. *Experiment 4 Condition Effects for Overall ANOVA and Planned Subsidiary ANOVAs*

Latency region (ms)	Overall[a]			Subsidiary[b] C vs. 1st		C vs. U		C vs. P		P vs. 1st	
	F	ε	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
300–400											
Midline	3.63	0.927	.022	8.73	.010	0.19	.671	4.44	.050	0.73	.403
Lateral	3.37	0.917	.030	10.93	.001	1.22	.285	4.96	.040	0.16	.689
400–500											
Midline	4.04	0.765	.021	10.88	.004	0.19	.670	7.73	.013	0.23	.635
Lateral	3.42	0.826	.033	10.83	.004	0.53	.122	7.07	.017	0.01	.948
500–600											
Midline	7.43	0.769	.001	12.84	.002	0.29	.598	8.87	.008	0.13	.726
Lateral	3.86	0.814	.022	7.26	.015	0.18	.673	3.98	.062	0.04	.854
600–700											
Midline	7.66	0.918	.006	18.30	.001	0.41	.527	5.86	.027	0.77	.390
Lateral	5.50	0.827	.005	21.46	.001	0.18	.676	4.01	.062	0.70	.411
700–800											
Midline	5.51	0.776	.006	15.01	.001	0.41	.531	2.50	.133	2.04	.172
Lateral	5.83	0.768	.004	19.38	.001	0.50	.487	2.32	.146	2.30	.148

[a]Degrees of freedom are 3 and 51. [b]C = crossed repeats; 1st = first presentations; U = uncrossed repeats; P = partial repeats. Degrees of freedom are 1 and 17.

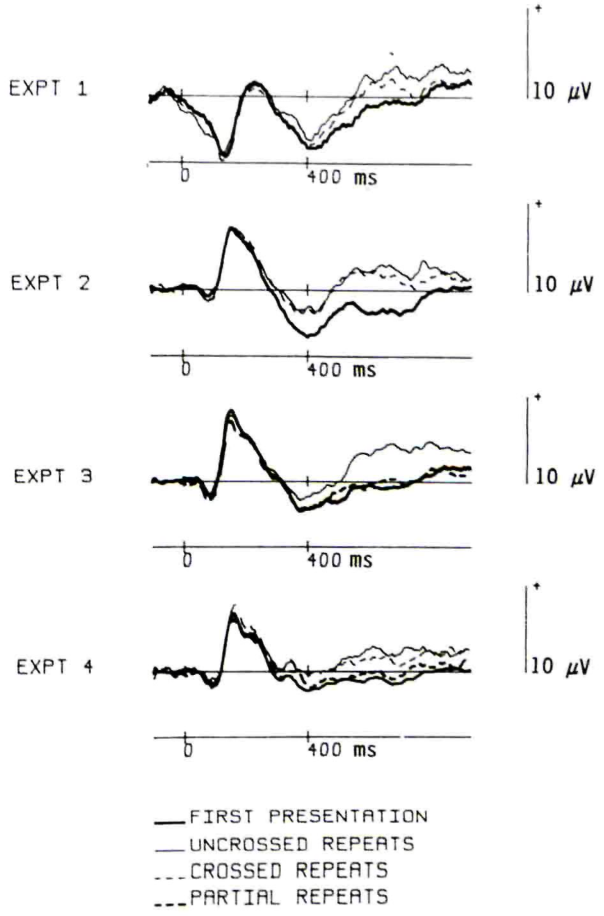

Figure 5. Grand average waveforms from the Cz electrode, illustrating the critical experimental conditions from each of the four experiments.

sodic associations between previously unrelated word pairs (e.g., Schacter & Graf, 1986; Smith, Macleod, Bain, & Hoppe, 1989). Nonetheless, it is possible that a task encouraging more elaborative or extensive processing of word pairs would have allowed local context to exert an effect. Furthermore, Musen and Squire (1993) have recently reported that in two indirect tests of memory (reading speed and tachistoscopic identification), a single study episode with a previously unassociated word pair does not lead to a processing advantage for words subsequently presented in the same rather than in different pairings. Such an advantage was observed however after pairs had been presented for study on multiple trials. These results raise the possibility that differential ERP repetition effects for crossed and uncrossed repetition might have developed if repetitions had occurred more than once.

At first glance, comparison of the present results with those of Besson and Kutas (1993) might suggest that sentence contexts are a more potent modulator of ERP repetition effects than are single words. This conclusion may be premature however, because Besson and Kutas's study omitted the condition – the pairing of a repeated sentence fragment with a repeated terminal word first presented in a different sentence – analogous to the crossed repetitions of the present study. It will not be possible to assess whether sentence and single word contexts are equivalent until ERP repetition effects in this condition have been compared with those evoked by terminal words repeated in the same context.

Despite the absence of direct evidence, the results of Besson and Kutas (1993) nonetheless suggest that the contextual manipulations employed in their study may indeed have effects different from those of the manipulations employed here. After the first presentation of a list of sentences, Besson and Kutas carried out a cued recall test in which subjects had to retrieve the terminal word of each sentence in response to the cue provided by the preceding sentence fragment. When the sentences were subsequently repeated in their entirety, ERP repetition effects were found only for terminal words that had been correctly retrieved in the intervening test of cued recall. Thus, long-term ERP repetition effects for sentence endings appear to be confined to items that subjects are able explicitly to predict from the prior context. In contrast to the experiment of Besson and Kutas (1993), the design of the present studies affords minimal opportunity to use context as a predictive cue. It will be of interest to determine whether Besson and Kutas's findings hold when single words, rather than text, are employed as contexts and are presented in advance of test items.

If the ERP repetition effect in the present experiments does not reflect the consequences of reintegration within the same local context, what does it reflect? The data suggest that the processes reflected by the effect are indifferent to whether a repeated pair of items were first experienced on the same or on separate trials but are sensitive to whether both or only one member of an item pair had recently been experienced. This pattern of results is reminiscent of the phenomenon of *list-wide* priming described by Smith et al. (1989).[5] Smith et al. compared response times to repeated target words preceded by one

[5]We are indebted to M. Besson for drawing our attention to the potential relevance of list-wide priming.

of three types of prime: words new to the experiment, words that had previously been studied in association with the target word, and words that had previously occurred in the same study list as the target but had been paired with a different target. Smith et al. (1989) found that, irrespective of whether the prime–target pairs maintained or changed their pairings between study and test, targets primed by words appearing on the study list were responded to more quickly than were those paired with new items.

The present findings may provide an electrophysiological analogue of list-wide priming, the ERP repetition effects observed here reflecting the processes responsible for the benefit that accrues to a word repeated along with a fellow member of the study list. Because these processes are presently obscure, this hypothesis does little however to elucidate the functional significance of the ERP repetition effect.

A radically different explanation of the present results stems from the idea that the processes reflected by ERP repetition effects for word pairs are insensitive to interitem processing and are instead item specific. By this account, unrepeated items evoke ERPs that contain an N400-like negativity, and repeated items evoke ERPs in which this negativity is attenuated. Therefore, ERPs evoked by pairs of repeated words will exhibit repetition effects exactly as if each item had been presented singly. Only one additional assumption is needed to accommodate the findings from the partial repetition conditions of Experiments 3 and 4, namely, that the presence in a word pair of a single unrepeated item is sufficient to cause the generation of an asymptotic N400. Given this assumption, the absence of an ERP repetition effect for partial repeats is easily accounted for.

This explanation would seem to have the advantage of parsimony over alternatives proposing that ERP repetition effects for word pairs rely upon the formation of some kind of association between their members, the basis for which seems especially obscure in the crossed repeat condition of Experiment 4. It does however rest on the crucial assumption that pairs of unrepeated words evoke N400 (or functionally similar) components of no greater magnitude than those evoked by pairs comprising a repeated and an unrepeated item. Although there is currently no evidence to support this assumption directly, there is reason to think it plausible. Kutas, Hillyard, and Gazzaniga (1988) presented subjects with auditory sentence fragments followed by two visually presented words, one to each visual field. They included a condition in which the same semantically anomalous (in the context of the preceding fragment) word was presented bilaterally and another condition in which only one word was anomalous and the other was congruent. The large N400 that occurred in the ERPs for the mixed word pairs was only slightly smaller than that evoked by bilateral anomalies. This finding, which is analogous to those from the partial repeat condition of Experiments 3 and 4, suggests that the processes reflected by N400 are indeed maximally or nearly maximally engaged by the presentation of a single unprimed word, irrespective of the status of any accompanying item.

In conclusion, these experiments offer no support for the idea that ERP repetition effects for isolated words reflect the consequence of reintegrating a word with an unchanged local context. A parsimonious explanation of the present results follows from the assumption that the processes reflected by these effects are item specific and hence insensitive to whether interitem associations are maintained between successive presentations. It remains to be seen whether this explanation is valid and if so whether it holds when contextual factors are manipulated in other experimental paradigms.

REFERENCES

Baddeley, A. (1990). *Human memory: Theory and practice*. London: Erlbaum.

Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and Clinical Neurophysiology, 60*, 343–355.

Bentin, S., & Peled, B. S. (1990). The contribution of stimulus encoding strategies and decision-related factors to the repetition effect for words: Electrophysiological evidence. *Memory and Cognition, 18*, 359–366.

Besson, M., & Kutas, M. (1993). The many facets of repetition: A behavioral and electrophysiological analysis of repeating words in same versus different sentence contexts. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19*, 1115–1133.

Besson, M., Kutas, M., & Van Petten, C. (1992). An event-related potential (ERP) analysis of semantic congruity and repetition effects in sentences. *Journal of Cognitive Neuroscience, 4*, 132–149.

Carroll, M., & Kirsner, K. (1982). Context and repetition effects in lexical decision and recognition memory. *Journal of Verbal Learning and Verbal Behaviour, 21*, 55–69.

Craik, F. I. M. (1989). On the making of episodes. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness* (pp. 43–57). Hillsdale, NJ: Erlbaum.

de Groot, A. M. B. (1985). Word-context effects in word naming and lexical decision. *Quarterly Journal of Experimental Psychology, 37A*, 281–298.

Fischler, I., & Raney, G. E. (1991). Language by eye: Behavioral and psychophysiological approaches to reading. In J. R. Jennings & M. G. H. Coles (Eds.), *Handbook of cognitive psychophysiology: Central and autonomic system approaches* (pp. 511–574). Chichester: Wiley.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar*. Boston: Houghton Mifflin.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory and Cognition, 11*, 501–518.

Halgren, E., & Smith, M. E. (1987). Cognitive evoked potentials as modulatory processes in human memory formation and retrieval. *Human Neurobiology, 6*, 129–139.

Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implications for the role of N400 in language processing. *Psychophysiology, 30*, 47–61.

Jasper, H. (1958). The ten twenty system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10*, 371–375.

Johnston, W. A., Hawley, K. J., Plewe, S. H., Elliot, J. M. G., & De Witt, M. J. (1990). Attention capture by novel stimuli. *Journal of Experimental Psychology: General, 119*, 397–411.

Karayanidis, F., Andrews, S., Ward, P. B., & McConaghy, N. (1991). Effects of inter-item lag on word repetition: An event-related potential study. *Psychophysiology, 28*, 307–318.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207*, 202–205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*, 161–163.

Kutas, M., Hillyard, S. A., & Gazzaniga, M. S. (1988). Processing of semantic anomaly by right and left hemispheres of commissurotomy patients. *Brain, 111*, 553–576.

Kutas, M., & Van Petten, C. (1988). ERP studies of language. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in psychophysiology* (pp. 139–188). Greenwich, CT: JAI Press.

Masson, M. E. J., & Freedman, L. (1990). Fluent identification of repeated words. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16*, 355–373.

McCarthy, G., & Nobre, K. (1993). Modulation of semantic processing by spatial selective attention. *Electroencephalography and Clinical Neurophysiology*, *88*, 210–219.
McKoon, G., & Ratcliff, R. (1979). Priming in episodic and semantic memory. *Journal of Verbal Learning and Verbal Behaviour*, *18*, 463–480.
Musen, G., & Squire, L. R. (1993). On the implicit learning of novel associations by amnesic patients and normal subjects. *Neuropsychology*, *7*, 119–135.
Nagy, M. E., & Rugg, M. D. (1989). Modulation of event-related potentials by word repetition: The effects of inter-item lag. *Psychophysiology*, *26*, 431–436.
Otten, L. J., Rugg, M. D., & Doyle, M. C. (1993). Modulation of event-related potentials by word repetition: The role of selective attention. *Psychophysiology*, *30*, 559–571.
Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology*, *39*, 475–543.
Rugg, M. D. (1985). The effects of word repetition and semantic priming on event-related potentials. *Psychophysiology*, *22*, 642–647.
Rugg, M. D. (1987). Dissociation of semantic priming, word and nonword repetition by event-related potentials. *Quarterly Journal of Experimental Psychology*, *39A*, 123–148.
Rugg, M. D. (1990). Event-related potentials dissociate repetition effects of high and low frequency words. *Memory and Cognition*, *18*, 367–379.
Rugg, M. D., & Doyle, M. C. (1994). Event-related potentials and stimulus repetition in indirect and direct tests of memory. In H. Heinze, T. Munte, & G. R. Mangun (Eds.), *Cognitive electrophysiology* (pp. 124–148). Cambridge, MA: Birkhauser Boston.
Rugg, M. D., Furda, J., & Lorist, M. (1988). The effects of task on the modulation of event-related potentials by word repetition. *Psychophysiology*, *25*, 55–63.
Rugg, M. D., & Nagy, M. E. (1987). Lexical contribution to non-word repetition effects: Evidence from event-related potentials. *Memory and Cognition*, *15*, 473–481.
Scarborough, D. L., Cortese, C., & Scarborough, H. J. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, *3*, 1–17.
Schacter, D. L., & Graf, P. (1986). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *12*, 432–444.
Smith, M. C., Macleod, C. M., Bain, J. D., & Hoppe, R. B. (1989). Lexical decision as an indirect test of memory: Repetition priming and list-wide priming as a function of type of encoding. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *15*, 1109–1118.
Van Petten, C., Kutas, M., Kluender, R., Mitchiner, M., & McIsaac, H. (1991). Fractionating the word repetition effect with event-related potentials. *Journal of Cognitive Neuroscience*, *3*, 129–150.
Young, M. P., & Rugg, M. D. (1992). Word frequency and multiple repetition as determinants of the modulation of event-related potentials in a semantic classification task. *Psychophysiology*, *6*, 664–676.

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