LANGUAGE AND COGNITIVE PROCESSES, 1993, *8* (4) 533–572

In the Company of Other Words: Electrophysiological Evidence for Single-word and Sentence Context Effects

Marta Kutas

Departments of Cognitive Science and of Neurosciences, University of California, San Diego, California, USA

The qualitative and quantitative similarities between lexical and sentence-level context effects were assessed by means of scalp-recorded electrophysiological measures. Event-related brain potentials (ERPs) were recorded to the second of a pair of words in a delayed letter search task and to the final words of a series of sentences presented one word at a time, and read for meaning and subsequent recognition. The critical words in both context conditions varied in the degree to which they were semantically or associatively related to the preceding context. In both cases, the ERPs to the critical words were associated with N400 components whose amplitude varied with expectancy and association. Neither the latency nor scalp distribution of the early phase of these two N400 effects differed as a function of context; the effects differed only in amplitude, with the word-level effect being smaller. Thus, as indexed by the N400 effect, there appears to be a remarkable qualitative similarity between the processes subserving lexical and sentence-level context effects.

Requests for reprints should be addressed to Marta Kutas, Department of Cognitive Science, University of California, San Diego, La Jolla, CA 92093-0515, USA. E-mail: mkutas@ucsd.edu.

Thanks to K. Baldwin, C. Brown, S. Garnsey, P. Hagoort, P. Holcomb, R. Kluender, L. Tyler, C. Van Petten and J. Weckerly for editorial comments on a previous version of this manuscript and C. Brugman for many enlightening conversations. M. Kutas and some of the research described herein were supported by an RSDA from NIMH (MH00322) and grants from NICHD (HD22614) and NIA (AG08313). The data were recorded in the laboratory of Steven A. Hillyard, without whose encouragement and discussions this work would not have been completed. Many thanks to J. Hansen who kept the machines running and wrote elegant programs for data collection and analysis.

INTRODUCTION

Despite a consensus that words which fit with an established context are responded to more quickly or more accurately than words which do not fit with it, the actual role of context remains unknown. It has been assumed that determining whether the action of a single word context is the same or different than that of a sentence fragment or an entire discourse either in nature or in timing would put critical constraints on the types of mechanism(s) that could be responsible (Balota, Flores d'Arcais, & Rayner, 1990; Besner & Humphreys, 1991; Henderson, 1982; Simpson, 1991). On the one hand, if a single mechanism can account for context effects regardless of the size or nature of the linguistic context (i.e. if the difference is *quantitative*), then it is unlikely that the mechanism is automatic spreading activation of excitation along pre-established functional pathways among memory representations for words (i.e. logogens). It is difficult to envision how automatic spreading activation could account for sentential priming when none of the words in the sentence are lexically associated. On the other hand, if lexical and sentential context effects are *qualitatively* different, then any theory that invoked a single explanatory construct for them both could be dismissed outright.

The prevailing view holds that the processes leading to lexically based context effects are qualitatively different from those supporting sentential context effects. Specifically, in contrast to lexical priming, which is presumed to occur autonomously within the lexicon, sentential priming effects are attributed to deliberate integrative or reasoning processes that take place *after* a word has been accessed from the mental lexicon (Fodor, 1983; Forster, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979). On this view, it is argued that if sentence-level effects remain for sentences without lexical associates, then they must be due to strategic expectancy-based, integrative or semantic matching processes (see De Groot, 1985; Neely, 1991).

Until recently, this argument seemed persuasive since behavioural measures from a variety of tasks could be used to document differences between lexical and sentential priming effects (for a review, see Van Petten, this issue). Particularly compelling was the seemingly fragile nature of sentence-level priming effects under "normal" reading conditions. Indeed, it has been argued that sentence-level context effects are restricted to abnormal conditions such as highly constrained contexts, visually "degraded" stimuli, and very slow presentation rates—moreover primarily for below-average readers.[1] It was on the basis of such evidence that

[1]As this criticism is invariably levelled against electrophysiological studies of sentence processing as well, we return to this issue in the Discussion.

Henderson (1982), among others, concluded that lexical spreading activation cannot be the fundamental mechanism facilitating lexical processing during normal reading, thereby setting sentence context effects apart from interactions among single words.

Within the past 10 years, however, both the fragility of sentential priming effects and the obligatory nature of lexical priming have been questioned. Not only is there evidence for facilitated target word processing within sentences without any lexically related or associated words (Balota, Pollatsek, & Rayner, 1985; Fischler & Bloom, 1979; 1980; Stanovich & West, 1983; West & Stanovich, 1982), but there are also indications that lexical priming effects are more robust across intervening words when the words appear in a sentence or a discourse context (e.g. Foss, 1982). It has been further shown that significant priming effects are more likely to arise in syntactically structured, meaningful phrases than in random combinations of the same words (e.g. Foss, 1982; O'Seaghdha, 1989; Simpson, Peterson, Casteel, & Burgess, 1989). It also appears that even the presence of semantic associates is not sufficient to yield reliable semantic priming effects (e.g. Duffy, Henderson, & Morris, 1989; see Carroll & Slowiaczek, 1986, for absence of lexical associative priming across a clause boundary).

Most of the empirical evidence for context effects on word processing has come from comparisons of latencies to pronounce a word (i.e. naming task) or to make a lexical decision (i.e. to decide whether a string of letters is or is not a legal word) as a function of different prime types (e.g. related, neutral, unrelated) and priming contexts (e.g. single word *vs* sentence fragment). Various investigators have reported both lexical and sentential priming effects for either pronunciation latency or lexical decision time as the dependent variable (see Neely, 1991, for lexical effects; see Schwanenflugel, 1991, for sentential effects), although occasionally there are reports of failures to find sentence-level priming on pronunciation latency (Forster, 1981; Masson, 1986). Even when both these latency measures do show some priming effects, the magnitude of these effects is generally found to be greater for lexical decisions (Neely, 1991). Both these observations have been ascribed in part to a post-lexical process directed by decision-related, strategic forces invoked by processing demands specific to the task (e.g. Balota & Chumbley, 1984; De Groot, 1985; Den Heyer, Briand, & Dannenbring, 1983; Neely, 1991; Seidenberg, Waters, Sanders, & Langer, 1984). As summarised by Tabossi (1991), "methodoligical problems are rather serious in the study of lexical processing, and are not restricted to one experimental paradigm only; hence it is very important that comparable results can be obtained with different techniques" (p. 6). Thus, one aim of the present study was to examine an alternative measure of how words are processed in the presence of lexical and sentential contexts.

Based on scores of experiments demonstrating that the same physical stimuli can yield different patterns of event-related brain potentials (ERPs)

as a function of processing demands made on a subject, the ERP waveform has been taken to offer one view of how stimuli are processed (Hillyard & Picton, 1987). ERPs recorded at the scalp are primarily a reflection of the summed inhibitory and excitatory post-synaptic potentials generated by the pyramidal cells in the cortex presumably involved in stimulus analysis and response preparation (e.g. Allison, Wood, & McCarthy, 1986; Dale & Sereno, 1993). ERPs can be similar or different along a number of different dimensions including waveshape, distribution of potential across the scalp, amplitude and latency. As a rule of thumb, differences in waveshape and/or scalp distribution between two or more conditions are interpreted as reflecting the activity of distinct neuronal populations subserving qualitatively different processes, whereas differences in amplitude and/or latency are interpreted as modulations in the activity of the same or related neuronal populations subserving processes that differ quantitatively.

This experiment was thus designed to use electrophysiological measures to make a direct comparison between lexical and sentential contexts on a word's processing with the specific aims of determining first whether the ERP effects would be the same or different and whether the difference, if any, was quantitative or qualitative. Given the assumptions outlined above, differences in the waveshapes of the ERPs associated with word- and sentence-level context effects would be taken as evidence for different underlying mechanisms, whereas similarity of ERP morphology would be taken to reflect the same underlying process. If the ERP waveforms indicated that lexical and sentential context effects were similar, then differences in amplitude and/or latency could be used to make inferences about the relative strengths and time-courses of the two different types of context effects. If the assumptions are granted, then it would seem that any account of how context influences word processing that proposes different mechanisms underlying lexical and sentential effects would predict a difference in the associated ERP componentry. Moreover, any account that maintains that lexical effects must precede sentential effects would predict that ERP context effects would occur earlier in the waveform following a single word than following a sentence context.

Electrophysiological findings from a number of different laboratories employing a host of experimental paradigms show that the earliest sign of semantic context on the ERP that is reliably found is on the N400 component (between 200 and 600 msec post-stimulus onset). Many studies attest to the systematic and reliable variation in N400 amplitude in response to the same experimental manipulations of semantic contexts that have been found to influence behavioural measures. For example, Kutas and Hillyard (1980a; 1980c) found that unlike the ERPs to highly expected words in congruent sentences, the ERPs to semantically anomalous words

include a broad, posteriorly distributed negative wave peaking around 400 msec. Several experiments since have demonstrated that semantic violations are neither necessary nor sufficient to elicit an N400 (for reviews, see Kutas & Van Petten, 1988; Kutas & Kluender, in press). That is, it has been shown that the N400 is not just a general reaction to any unexpected stimulus within text but appears instead to be a part of the default response to any potentially meaningful item such as a word or pseudoword-like lexical strings, line drawings, real pictures, or various handshapes from American Sign Language (Besson & Macar, 1987; Holcomb & Neville, 1991; Kutas & Hillyard, 1980b; 1980c; 1983; Kutas, Neville, & Holcomb, 1987; McCallum, Farmer, & Pocock, 1984).

While the ERPs to all meaningful items seem to possess some N400 activity, there is considerable variability in its amplitude. Two of the factors that are especially powerful modulators of N400 amplitude are contextual constraint and semantic association and/or relation.[2] The effect of contextual constraint on N400 amplitude has been assessed in two ways. Initially, Kutas and Hillyard (1984) crossed several levels of contextual constraint with several levels of cloze probability and showed that N400 amplitude was correlated with the cloze probability of the final word but generally independent of the contextual constraint of the preceding sentence fragment (see also Kutas, Lindamood, & Hillyard, 1984). This result was critical in establishing that N400 amplitude does not index the violation of previously established expectancies for a particular word which was not presented, but rather is sensitive to the degree to which the sentence fragment prepared the way for the word which actually followed. Note, however, that in the absence of an explicit attempt to dissociate cloze probability and contextual constraint, the two factors are generally correlated. From a different perspective, Van Petten and colleagues (Kutas, Van Petten, & Besson, 1988; Van Petten & Kutas, 1991a; 1991b) exploited the English speaker's reliance on word order for interpretation and used a word's ordinal position within its sentence to estimate the amount of contextual constraint to which it was subject. What they observed was a linear decline in the amplitude of the N400 component of ERPs to content words across the course of a sentence, dubbed the "word-position effect". As this reduction with ordinal position was absent in the response to random word strings and syntactically structured but semantically anomalous sentences alike, it was reasoned that it was primarily the accumulation of *semantic* constraints in conjunction with only minimally effective struc-

[2]It may be possible to subsume both these factors under a single larger heading, but for the moment I will continue to separate them as this facilitates the explanation of the various experiments in which they have been manipulated.

tural constraints that had led to the reduction in N400 amplitude (for a review, see Van Petten & Kutas, 1991c).

The results of these and similar experiments using sentences have also pointed to an important link between semantic processes and N400 amplitude (for a review, see Kutas & Van Petten, 1988). For example, the N400s following meaningful but unlikely completions for sentences that were highly contextually constrained were found to differ in amplitude as a function of the semantic association between the most highly expected word (i.e. best completion) and the ending actually presented. Specifically, smaller N400s followed words that were semantically or associatively related to the best completions for those same sentences than followed words that were unrelated; this has since been referred to as the "related anomaly effect" (Kutas & Hillyard, 1984). Similar results obtained even when the sentence terminal words were semantically anomalous (Kutas et al., 1984). These data were interpreted as consistent with the view that the sentence fragments initiate an activation process that primed not only the most expected endings but also its nearby semantic associates, even those that are highly improbable or nonsensical, possibly in part via the action of an automatic, unconscious mechanism (Kutas & Hillyard, 1984).

Based on these results, it was reasonable to question whether the N400 would be sensitive to the semantic relationships or associations between words presented in isolated pairs as well as those in meaningful sentences. And, indeed, whenever ERPs have been recorded during some of the more common behavioural priming paradigms, such as lexical decision (Bentin, McCarthy, & Wood, 1985; Holcomb, 1988) and category membership judgement tasks (Boddy, 1986; Boddy & Weinberg, 1981; Harbin, Marsh, & Harvey, 1984; Polich, Vanasse, & Donchin, 1981), late negativities bearing a striking resemblance to the N400 elicited in sentences have been observed. Under such circumstances, the largest N400s have been seen following unprimed or out-of-category words and pseudowords (that is, orthographically legal, pronounceable nonwords); in other words, N400 amplitude is reduced to the extent that the eliciting word is related to a prior experimental word.

By the nature of the tasks in which they were generated, namely the requirement for a binary decision, these non-sentential N400s almost without exception have been elicited together with an ensuing late positivity (e.g. P300 component). In some cases, the presence of this late positivity has made it difficult to determine the scalp distribution of the preceding or coincident N400 component, although it has generally been reported to be more frontal in the word pair versus sentence situations. Comparisons across experimental situations have been particularly difficult, since the stimuli, tasks, recording sites and subjects were all different. Thus, the present experiment was designed to allow as direct a

comparison as possible between the ERPs, especially the N400 component given its sensitivity to lexical and sentential contexts, from the same recording sites within a single set of subjects to a similar set of word stimuli serving as terminal words in a sentence reading paradigm or as target words in a word pair paradigm. In addition, to avoid the possible confounding between semantic processes and decision-related processes, a word-pair task was chosen which previous work had shown to provide a clear view of the N400 unadulterated by decision-related late positivities (Kutas & Hillyard, 1989).

METHODS

Subjects

Sixteen young adults (10 females, 6 males) aged 18–33 years were paid for participating in the experiment. All but one of the subjects were right-handed according to self-report and the Edinburgh Inventory (Oldfield, 1971), and seven of them had left-handed relatives in their immediate family.

Stimuli

Words were displayed in the form of brightened dot matrices on a CRT controlled by an Apple II microcomputer. All words were exposed for 132 msec and ranged in length from 1 to 13 letters. The subjects sat approximately 33 inches from the screen.

Recording System

EEG activity was recorded from eight scalp electrodes, each referred to linked mastoids. Four were placed according to the International 10-20 system at frontal (Fz), central (Cz), parietal (Pz) and occipital (Oz) midline locations. Symmetrical anterior-temporal electrodes were placed halfway between the F7 and T3 and F8 and T4 sites, respectively. Symmetrical posterior-temporal electrodes were placed lateral (by 30% of the interaural distance) and 12.5% posterior to the vertex. In addition, eye movements were monitored for vertical movements and blinks via an electrode placed below the right eye and referred to the mastoids and via a right-to-left canthal bipolar montage for horizontal movements.

The midline and EOG recordings were amplified with Grass 7P122 preamplifiers (system bandpass DC to 35 Hz, half-amplitude cut-off). The EEG from the lateral scalp leads was amplified with Grass 7P511 preamplifiers modified to have an 8 sec time constant (high-frequency half amplitude cut-off = 60 Hz).

Analog-to-digital conversion of the EEG, EOG and stimulus trigger codes was performed online by a PDP11/45 computer. A 1024 msec epoch of EEG beginning 100 msec before the onset of each stimulus was analysed at a sampling rate of 250 Hz.

Procedure

The subjects were tested in one session that lasted 2½–3 h, while reclining in a comfortable chair. Prior to the ERP recordings, each subject was given a reading test for speed and comprehension, the Level II pronunciation and spelling subtests of the Wide Range Achievement Test, and a handedness questionnaire.

The experimental session was divided into two parts. In the initial phase, the subjects read sentences for content, whereas in the second phase they made decisions about the presence or absence of a probe letter following pairs of words that had been derived from sentence stimuli.

All the subjects were presented with one of two sets of 160 different variable length sentences (ranging between 5 and 13 words in length), presented one word at a time at an interword interval (onset-to-onset) of 700 msec. The inter-sentence interval from the final word of a sentence to the initial word of the next one was 2800 msec. All of the sentences were characterised by medium to high contextual constraint (leading to completions with cloze probabilities of 0.75 or greater) and were semantically meaningful. Some of the sentences were selected from Bloom and Fischler (1980); the contextual constraints of the remainder were determined via a cloze procedure on 25 subjects who did not take part in the present experiment. Half the sentences ended with the most likely response ("best completion") for that sentence, whereas the other half ended with a meaningful but less probable word (cloze probabilities of endings, half were words semantically related to the best completion for that sentence and half were semantically unrelated to the best completion for that sentence) (see Appendix 1).

The subjects were instructed to read the sentences silently in order to complete a questionnaire about their contents after all the sentences were presented. The sentences were presented in two sets of 80 each. Half the subjects read one set of 160 sentences and the other half saw a different set of 160 sentences.

Following the ERP recording, the subjects were given a recognition/memory questionnaire including 37 sentences each missing the terminal word. Approximately half the carrier sentence fragments were "new" and half were "old". The subjects were asked to discriminate between those previously seen and those that were "new". In addition, in the case of "old" sentences, they were asked to recall the terminal words actually

presented, while in the case of the "new" sentences they were asked to provide the word they considered to be the most likely ("best") completion.

For the second phase of the experiment, the subjects were presented with word pairs followed by a probe letter. For each word pair, the subjects saw the first word (132 msec) followed 700 msec later (onset-to-onset) by the second word (132 msec). Following the second word by a delay of 1200 msec, a letter punctuated by a question mark was flashed for 249 msec. The subject's task was to despress one key on a keypad if the letter had been present in either or both of the words in the pair and to depress a different key if the letter had not been present. Responses were performed by the index and middle fingers of the dominant hand. The presentation of the next trial was contingent upon the completion of the response to the previous trial and followed the key depression by 1800 msec.

The word pairs in the second half of the experiment were derived from the sentences. In each case, the second word of the pair was the final word of one of the 320 aforementioned sentences. For the sentences which ended with a low cloze probability word, the first word of the pair was the word that was the best completion for the sentence in which the low cloze probability word had occurred. For example, the moderately related word pair derived from the sentence "They raised pigs on their ranch" was farm–ranch and the unrelated word pair derived from the sentence "Fred put the worm on the table" was hook–table. For the sentences which terminated with the best completion, the first word was determined by selecting a word semantically related or associated with the best completion; in some cases, this was a previous word in the sentence. For example, for the sentence "Before exercising Jack always stretches his muscles", the pair was biceps–muscles, and for the sentence "Every Monday morning the gardener mows the lawn", it was mow–lawn. Approximately 70% of the related word pairs were related by virtue of a categorical relationship, including near-synonymic and antonymic (e.g. tablet–pill, milk–cream, thread–string, light–dark). The remainder were situational (e.g. thermometer–temperature, quarterback–football), featural (e.g. shingle–roof, month–year), lexical, including primarily compound nouns (e.g. bulletin–board, bunk–bed), and a few substrate–superstrate relations (e.g. window–glass, ice cream–sundae).

All 320 word pairs generated in this way were presented to all the subjects. The sequence of presentation of the word pairs was the same as it had been when the sentences from which they were generated were presented. Across subjects, ERPs to the same words could be examined when they were preceded by a sentence context and when they were preceded by a related word. In addition, within each subject, half of the second words in the word-pair phase of the study had been previously seen

as a sentence terminal word and half were new. Thus, half the subjects were presented with the word pairs derived from the sentences which they did not read in Phase 1 of the experiment first ("new" word pairs) followed by the word pairs generated from the sentences they had read ("old" word pairs). The other half of the subjects experienced the "old" word pairs followed by the "new" word pairs.

Of the 320 word pairs, 46% were classified as highly related semantically, 25% were moderately related and the remaining 29% were semantically unrelated (see Appendix 2). In most cases, the degree of relation between the words was determined from association and category norms of word production (Battig & Montague, 1969; Postman & Keppel, 1970). Additional word pairs were generated and classified as to semantic association on the basis of experimenter judgements and usage by previous investigators (e.g. Meyer & Schvaneveldt, 1971). These *a priori* semantic classifications were validated in behavioural studies with two independent groups of subjects. In the first, 11 subjects (different from those in the present experiment) were asked to produce an associate to each of the 320 words as quickly as possible. For this group of subjects, the probability that the second word chosen by the experimenter was given as a response to the first word was 0.47 for the highly related condition, 0.08 for the moderately related condition, and 0.00 for the unrelated condition. The presence of semantic priming effects with these stimuli was also verified by a second group of subjects in a naming task (see Kutas & Hillyard, 1989).

The second word of each highly related pair averaged 4.99 letters in length (range 2–11) and had a median frequency in the English language of 93. The second word of each moderately related pair averaged 5.43 letters in length (range 3–12) and had a median frequency in the English language of 60. The second word of each unrelated pair averaged 5.64 letters in length and had a median frequency of 60.

RESULTS

Sentence Terminal Words

The grand average ERPs (n = 16) to sentence-final words from all the recording sites are displayed in the left-hand column of Fig. 1 (the data in the right-hand column from the word-pair task, displayed here for the purpose of direct comparison, will be discussed later). Final-word ERPs, like the responses to initial and intermediate words, include the early P1, N1 and P2 components; these do not differ as a function of the type of ending. The major difference between the three ending types onsets after the P2 component. Highly probable congruent endings (i.e. best comple-

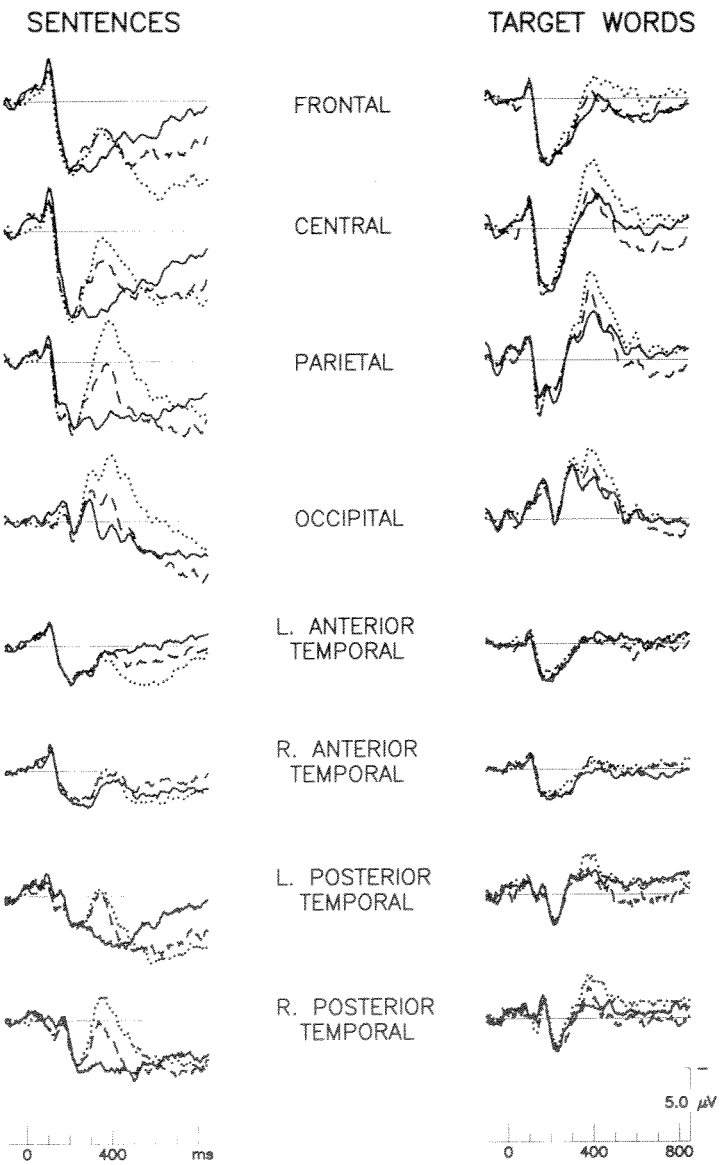

FIG. 1 Comparison of the grand average (n = 16) ERPs elicited by sentence-final words (left column) and the second words of the "new" prime–target word pairs (right column). For the sentences, the ERPs to the best completions or high cloze probability endings (solid line), low cloze probability endings semantically related to the best completions (dashed line) and the low cloze probability endings that were unrelated to the best completions (dotted line) are superimposed. For the word pairs, the ERPs to the second word of highly related (solid line), moderately related (dashed line) and unrelated (dotted line) pairs are superimposed.

TABLE 1
Mean (± SD) ERP Amplitudes (in μV) of Sentence-final Words for Two Consecutive Windows

	Best Completions	*Low Cloze Related*	*Low Close Unrelated*
300–500 msec			
Frontal	3.37 ± 0.71	2.94 ± 1.04	3.02 ± 1.33
Central	4.93 ± 0.73	3.09 ± 0.93	1.56 ± 1.27
Parietal	3.93 ± 0.78	1.64 ± 0.87	−1.30 ± 1.27
Occipital	0.62 ± 0.45	−0.88 ± 0.62	−3.68 ± 0.55
L. ant. temporal	0.59 ± 0.38	0.95 ± 0.68	1.56 ± 0.60
R. ant. temporal	1.19 ± 0.38	0.69 ± 0.62	0.86 ± 0.65
L. post. temporal	3.21 ± 0.59	1.83 ± 0.74	1.07 ± 0.77
R. post. temporal	3.51 ± 0.51	1.81 ± 0.66	−0.19 ± 0.91
500–900 msec			
Frontal	1.42 ± 0.67	3.38 ± 0.69	5.77 ± 0.97
Central	2.41 ± 0.59	4.00 ± 0.63	4.48 ± 0.94
Parietal	3.05 ± 0.44	4.29 ± 0.58	2.69 ± 1.09
Occipital	2.31 ± 0.43	3.06 ± 0.71	0.58 ± 0.85
L. ant. temporal	−0.39 ± 0.35	0.64 ± 0.34	1.76 ± 0.38
R. ant. temporal	1.47 ± 0.43	0.73 ± 0.46	1.88 ± 0.47
L. post. temporal	1.20 ± 0.43	3.21 ± 0.55	4.03 ± 0.77
R. post. temporal	2.81 ± 0.38	3.48 ± 0.49	2.97 ± 0.88

tions) are characterised by a broad, late positivity with a centro-parietal distribution (solid tracing) which is approximately 0.5 μV larger over the right than the left hemisphere [mean amplitude 300–900 msec: main effect of anterior-posterior position, $F(1,15) = 54.89$, $P < 0.001$; main effect of hemisphere, $F(1,15) = 17.98$, $P < 0.001$].[3] In contrast, the responses to both types of low cloze probability endings sport a clear posteriorly distributed, negative component (N400) with a right hemisphere predominance that is superimposed on the positive shift [for mean amplitude 300–500 msec: effect of ending type, $F(2,30) = 10.18$, $P < 0.001$; effect of electrode site, $F(7,105) = 9.14$, $P < 0.001$; ending type × site interaction: $F(14,210) = 14.61$, $P < 0.001$].

While the ERPs to the two different types of low cloze probability endings both contain notable N400s, the responses are not identical. The unrelated endings elicit larger and more prolonged N400s (by 50–100 msec) than the related endings. Specific comparisons substantiate the

[3]The asymmetry was significant for both the early (300–500 msec) and the late (500–900 msec) measurement windows of the high cloze probability congruous endings, collapsed in the 300–900 msec measure for the sake of brevity.

significant three-way differentiation in the region of the N400 (i.e. between 300 and 500 msec) among the three ending types (mean amplitudes and standard errors are also shown in the top half of Table 1). The N400s to both the related and unrelated low cloze endings differ significantly from the response to the high cloze probability endings as well as from each other [effect of ending type for related *vs* unrelated: $F(1,15) = 6.96$, $P < 0.018$; site × ending interaction: $F(7,105) = 11.18$, $P < 0.001$]. Like the N400 itself, the ERP difference due to semantic association is most noticeable posteriorly at the parietal, occipital and right temporoparietal sites. While the N400 is in all cases somewhat larger over the right than the left hemisphere, this asymmetry is quite evident in the ERPs to terminal words unrelated to the expected best completions and appears only as a tendency in the ERPs to related endings [mean amplitude 300–500 msec, ending type × hemisphere interaction: $F(1,15) = 5.43$, $P < 0.03$].

The ERPs to the various classes of endings also differ in the post-N400 region between 500 and 900 msec post-stimulus. Specifically, low cloze probability words are associated with a significantly larger late positivity than are the high cloze probability endings [mean amplitude 500–900 msec, ending × site interaction: $F(14,210) = 9.28$, $P < 0.001$, epsilon = 0.24]. As can be seen in the bottom half of Table 1, this positivity has a frontal maximum and is somewhat larger for endings unrelated to the expected completions than for related endings [for related *vs* unrelated low cloze endings, mean amplitude 500–900 msec, ending type × site interaction: $F(7,105) = 11.29$, $P < 0.001$, epsilon = 0.26].

Memory/Recognition Questionnaire

The subjects correctly recognised an average of 79% (range 55–94%) of the old sentences and misclassified only 11% of the new sentences on the list as belonging to the set they had just seen. They correctly completed an average of 58% (range 33–78%) of the final words for the sentences they had been shown; this broke down into approximately 41, 45 and 87% correct for the low cloze probability unrelated, related and best completions, respectively.

ERPs to "New" Word Pairs

The ERPs to the word pairs generated from the sentences that subjects did not see ("new") are presented in the left-hand column of Fig. 2. The ERPs elicited by the first word (potentially "priming" word) in each pair are characterised by N1-P2-P3-like components, followed by a late positivity parietally and a return to baseline at the other midline locations. There are no statistically significant differences among the three superimposed wave-

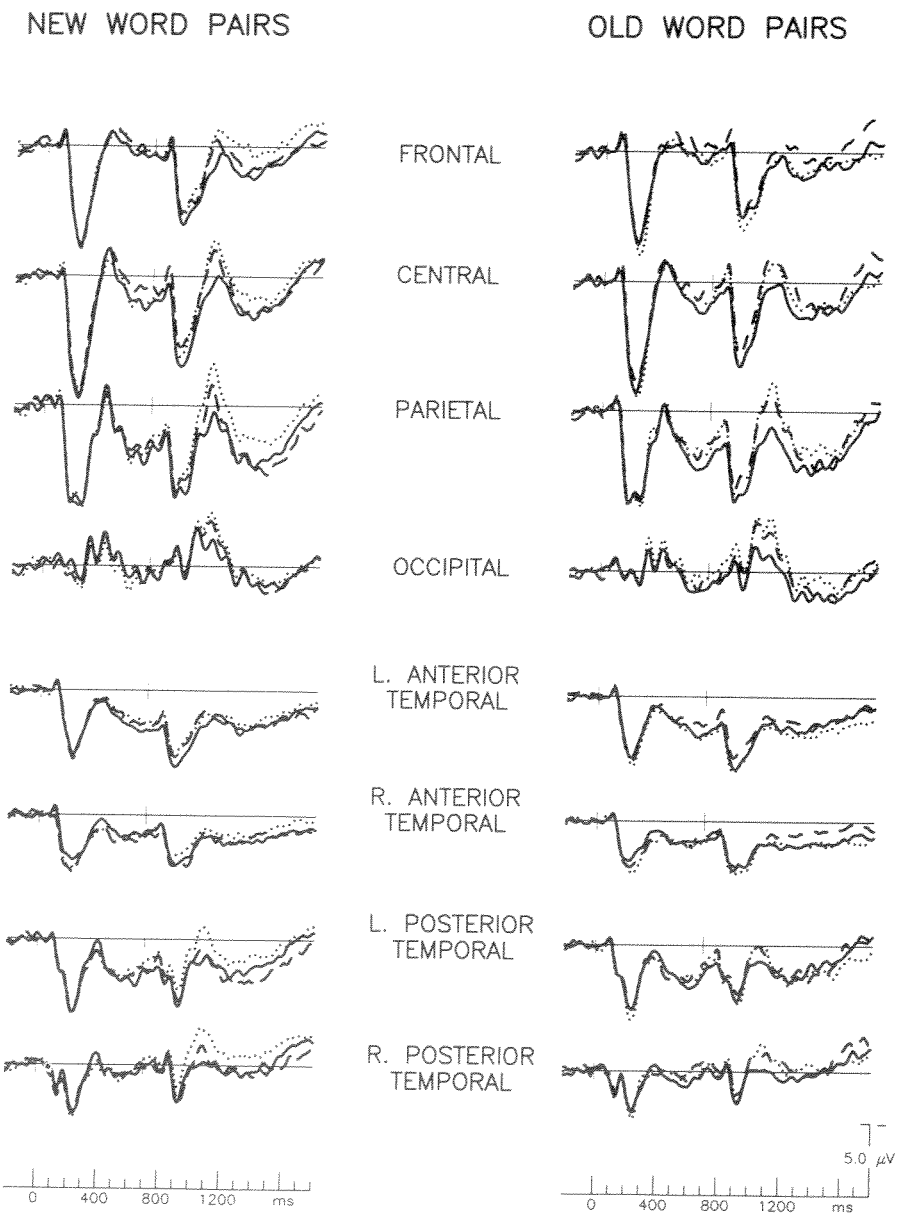

FIG. 2 Grand average (n = 16) ERPs to both words of the "new" and "old" word pairs at all the recording sites. The ERPs to highly related (solid line), moderately related (dashed line) and unrelated (dotted line) word pairs are superimposed. Interword interval was 700 msec.

forms as a function of the semantic relation of this eliciting word to the following word in the pair. Thus, whatever effects appear later in the ERP are not due to residual differences in initial word characteristics of processing.

The morphology of the average ERPs elicited by the second ("target") words is similar in most regards to that of the response to the first words. However, the second-word ERPs differ from those to first words in that they have reduced P2 amplitudes and an enhanced negativity (N400) in the 300–500 msec region. This negativity is remarkably similar in shape and scalp distribution to the N400 elicited by the low cloze probability sentence terminal words, although in the case of the word-pair ERPs, the N400 is not superimposed upon a large positive shift (see right-hand column of Fig. 2). Like the N400s to sentence terminal words, those elicited by these second words in word pairs have a posterior maximum [for mean amplitude 300–500 msec, main effect of site: $F(7,105) = 11.20$, $P < 0.0002$, epsilon = 0.31].

While the ERPs to all three types of second words show some N400 activity, as in the case of sentence terminal words, its amplitude varies as a

TABLE 2
Mean (± SD) ERP Amplitudes (in μV) of the 300–500 msec Region of ERPs to Target Words from the "New" and "Old" Word Pairs

	Highly Related	*Moderately Related*	*Unrelated*
New pairs			
Frontal	0.89 ± 0.60	0.59 ± 0.78	−0.50 ± 0.81
Central	−1.35 ± 0.86	−1.35 ± 0.88	−3.15 ± 0.97
Parietal	−2.24 ± 0.94	−2.72 ± 0.99	−4.15 ± 0.93
Occipital	−2.52 ± 0.57	−2.95 ± 0.76	−4.06 ± 0.65
L. ant. temporal	0.37 ± 0.30	−0.21 ± 0.38	−0.15 ± 0.32
R. ant. temporal	−1.23 ± 0.32	−0.07 ± 0.31	−0.15 ± 0.43
L. post. temporal	−0.77 ± 0.35	−0.92 ± 0.39	−1.86 ± 0.32
R. post. temporal	0.59 ± 0.46	−0.74 ± 0.56	−2.05 ± 0.51
Old pairs			
Frontal	0.65 ± 0.58	0.11 ± 0.45	0.33 ± 0.49
Central	−0.40 ± 0.40	−0.42 ± 0.47	−0.98 ± 0.57
Parietal	−1.32 ± 0.48	−0.85 ± 0.60	−1.59 ± 0.57
Occipital	−0.90 ± 0.55	−1.02 ± 0.53	−1.19 ± 0.47
L. ant. temporal	−0.71 ± 0.25	−0.20 ± 0.34	−0.29 ± 0.29
R. ant. temporal	0.18 ± 0.24	−0.24 ± 0.21	0.27 ± 0.28
L. post. temporal	−1.22 ± 0.34	−0.59 ± 0.29	−0.49 ± 0.30
R. post. temporal	−0.60 ± 0.35	−0.58 ± 0.33	−0.74 ± 0.37

function of the semantic or associative relation to the immediately preceding word [main effect of prime–target relation: $F(2,30) = 5.82$, $P < 0.007$; relation to prime (first word) × electrode site interaction: $F(14,210) = 2.13$, $P < 0.01$, epsilon = 0.29]. The largest N400s are elicited by "unprimed" second words, that is, words unrelated semantically or associatively to the first words. Specific comparisons of the mean amplitudes of the ERPs at 300–500 msec post-stimulus (see Table 2) indicate that the N400 to unrelated words is larger than that to primed (i.e. related) words whether they are moderately [main effect of prime–target relation: $F(1,15) = 5.96$, $P < 0.027$] or highly related [main effect of prime–target relation: $F(1,15) = 16.23$, $P < 0.001$; prime–target relation × site interaction: $F(7,105) = 3.48$, $P < 0.04$, epsilon = 0.34]. The N400 amplitudes elicited by the semantically related words derived from the related sentences and those derived from the high cloze sentences with best completions do not differ from each other significantly.

While visual inspection indicates a slight right hemisphere amplitude bias to the N400 following unrelated words, neither this asymmetry nor a similar measure (300–500 msec) for the related ERP waveforms is statistically significant.

ERPs to "Old" Word Pairs

As can be seen in the right-hand column of Fig. 2, the ERPs elicited by the word pairs derived from the sentences that the subjects had read in the first phase of the experiment (i.e. "old" pairs) are in most respects the same as those elicited by the "new" word pairs. The ERPs to the first (prime) words sorted according to their semantic relation with the following (target) words do not differ significantly from each other in any way. The ERPs to the second words of the pairs are like the "new" word pairs characterised by an N400 component. The "old" second-word N400s are slightly smaller in amplitude than the "new" N400s on the whole; this can reasonably be viewed as a repetition effect. While the pattern of N400 semantic priming effects for the old word pairs is essentially the same as that for the new word pairs, the main effect of semantic relation is not statistically reliable.

Behaviour/Reaction Times to Word Pairs

The subjects generally took between 1 and 3 sec to respond to the probe letter. They responded approximately 300 msec faster to letter-present (1297 ± 288 msec) than to letter-absent (1618 ± 447 msec) trials [$F(1,12) = 37.03$, $P < 0.001$].

Comparison of N400 Effect in Sentences and "New" Word Pairs

To allow a more direct comparison of the largest context effects in the two experimental conditions, difference wave ERPs were computed. For the sentences, this entailed subtracting the ERPs to high cloze probability endings point by point from the ERPs to the unrelated low cloze probability endings. Likewise, for the "new" word pairs, the responses to the highly related target words were subtracted from those to the unrelated target words. The resultant difference waves for the two context conditions are displayed in Fig. 3. The actual difference wave ERPs thus obtained are shown in the left-hand column. The waveforms in the right-hand column are essentially the same, with the exception that the word-pair ERPs were multiplied by a scalar in an attempt to equate the amplitudes of the N400 effects in the two experimental conditions.[4] In so doing, it is possible to get a clearer picture of the potential differences in the onset and peak latencies and scalp distributions of the two N400 effects.

As can be seen in the right-hand column of Fig. 3, the N400 effect begins approximately 35 msec earlier in the sentence (281 $\pm$ 4.4 msec) than in the word-pair (316 $\pm$ 7.8 msec) condition [main effect of context condition: $F(1,15) = 6.09$, $P < 0.026$].[5] By contrast to the different onset latencies, the peak latencies of the N400s in the sentence (379 msec) and word-pair (380 msec) conditions were nearly identical.

DISCUSSION

The primary motivation for this study was to contrast lexical (e.g. word pair) and sentential context effects on the ERP in the same group of subjects. Since the actual ("raw") ERPs to the critical words in the two context conditions are expected to be different,[6] the contrasts of primary

---

[4]The scaling procedure was as follows: (1) choose a particular channel; any channel should do. In this case, the midline parietal site (which showed the largest N400 in the sentence condition) was chosen. Measure the amplitude of the N400 at this channel in the sentence condition. (2) Measure the amplitude of the N400 at the same channel at the same latency of the word-pair ERP. (3) Find the ratio between the two amplitudes. (4) Multiply every point of the ERP at each of the different locations by this value.

[5]Onset latency was estimated by first determining the latency of the peak negativity between 200 and 600 msec relative to a 100 msec pre-stimulus baseline at the central, parietal and occipital midline and the two lateral posterior sites. From the peak value, it was thus possible to estimate the latency at which 10% of the amplitude at the peak is reached; this value is taken as an estimate of the onset latency of the N400 effect.

[6]For example, it is well known that the ERPs to words occurring at the end of a sentence are generally more positive than at any other positions within the sentence. It has been suggested that this positivity reflects the resolution of the long-lasting negativity (contingent negative variation or CNV) that builds during the course of the sentence (McCallum, 1988).

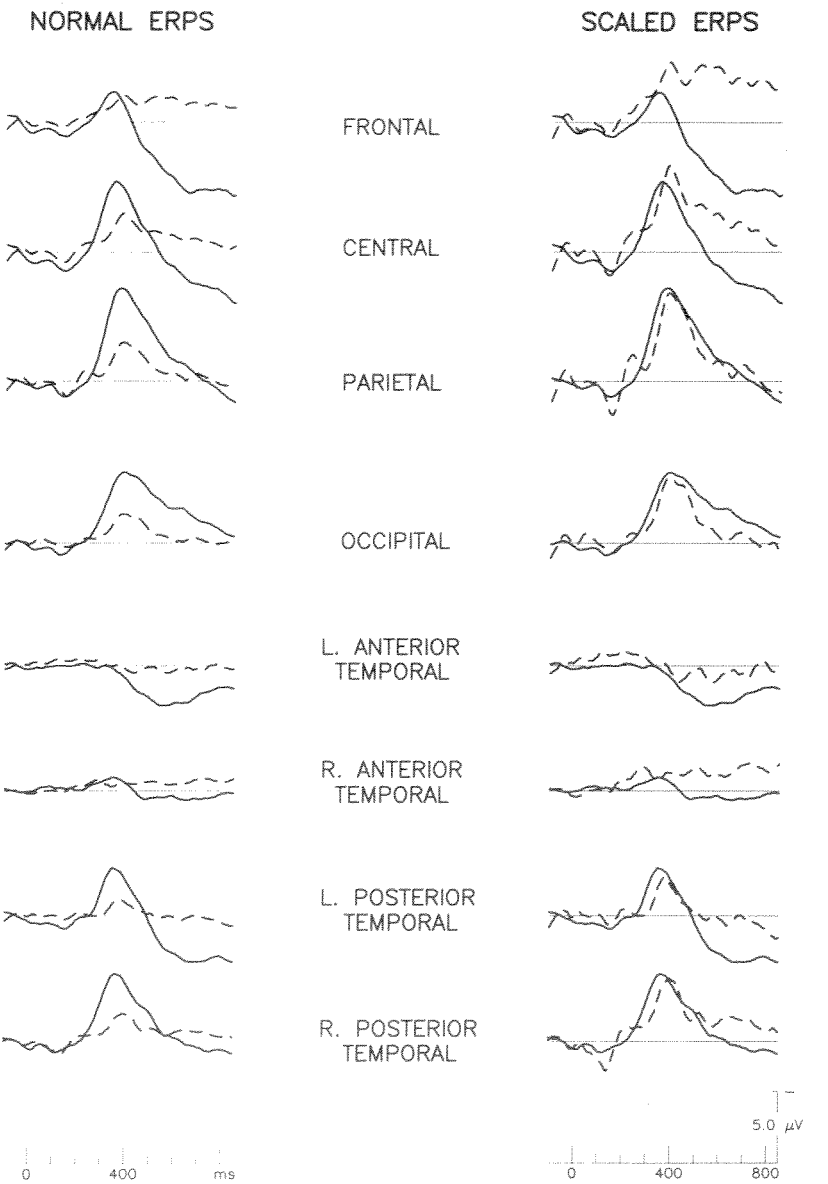

FIG. 3 Comparison of the grand average (n = 16) difference ERPs from the sentence (solid line) and "new" word-pair (dashed line) conditions. The data in the left-hand column are the actual waveforms formed when the ERPs to the high cloze endings are subtracted from those to the low cloze unrelated endings and the ERPs to the highly related target words are subtracted from the ERPs to the unrelated target words. The difference waveforms in the right-hand column represent a transformation of those in the left-hand column, whereby the ERPs from the word-pair condition are multiplied by a scalar that equates the amplitudes of the ERPs in the two conditions.

interest are the ERP context effects; these include the differences between the ERPs to the high and to the two types of low cloze probability endings in the sentence condition, and the differences between the ERPs to strongly and moderately related and unrelated second words in the word-pair condition. With these difference ERPs in hand, it will then be possible to assess the effects of context on the different parameters (e.g. amplitude, latency, scalp distribution) of the semantic context ERP effect. Specifically, we can ask whether these two ERP effects have the same morphology (i.e. waveshape) and distribution across the scalp; an answer in the affirmative will be taken as evidence for similar underlying mechanisms. In addition, we can examine the temporal course of these two context effects on the ERP.

Let us first examine how the findings relate to the existing literature on ERPs during sentence processing. Note that the present results replicate findings demonstrating that the N400 in sentences can be elicited by other than semantic anomalies, namely by meaningful but low cloze probability words (Fischler et al., 1983; 1984; Fischler, Childers, Achariyapaopan, & Perry, 1985; Kutas & Hillyard, 1984; Kutas et al., 1984). We also replicate the finding that the amplitude of the N400 to sentence-final words is smaller if the words are semantically related to the expected completions of the sentences than if they are unrelated (Holcomb & Neville, 1991; Kutas & Hillyard, 1984; Kutas et al., 1984). The possibility that the ERP to the sentence-final word may be susceptible to the prior activation of the representation of a word (or concept) that is never actually presented but merely anticipatd by virtue of a highly constraining context, is potentially very revealing about the role of top-down processes in language processing. However, it is first necessary to rule out alternative explanations. For example, the differential N400 amplitudes to the low cloze probability related and unrelated endings could simply reflect the fact that an on-line electrophysiological measure is more sensitive to contextual constraint than is an off-line cloze measure. Or perhaps our choice of cloze probabilities of less than 5% for the two low cloze conditions was too coarse a division and finer gradations would reveal that the unrelated endings are in fact of a lower cloze probability than the related ones. This explanation seems unlikely given that essentially the same effect of relatedness has been observed even for undeniably anomalous endings (e.g. "The game was called when it started to umbrella"), which have a cloze probability of zero (Kutas et al., 1984).

However, since no attempt was made to preclude lexical associates from these sentences, the reduced N400 to related low cloze probability endings could reflect the contribution of the occasional trial in which an ending is lexically primed by a previous word in the sentence. Approximately 25% of our sentences did contain a word that might be considered semantically

or associatively related to the sentence ending. On the whole, these relationships are very weak (e.g. food–platter, study–tests, parking–autos, speaking–syllable), raising doubts as to whether or not they would even yield behavioural or electrophysiological lexical priming effects in a word-pair task, much less in a sentence context. Generally, loosely related word pairs display either minimal or no benefits of lexical context via behavioural measures. Moreover, in the present study, each associated word was separated from the sentence-final word by two to five words on average. Typically, only when a prime and target occur consecutively in a list of items is significant behavioural priming observed; in fact, a single intervening word between a prime and a target is generally sufficient to eliminate facilitation of naming latency or lexical decision times in word-pair tasks (for a review, see Neely, 1991). Thus, in so far as the N400 reduction to related low cloze endings is attributable to simple relations among the words in the sentence, some top-down (sentence-level) influence on lexical processing is implicated. For it is only through the action of sentence-level influences that such weakly associated words separated by intervening words could nonetheless support priming effects. This interpretation of these data would be in line with the experiments by Foss (1982) showing that intra-lexical activations which would normally decay in a word-pair task are prolonged when the critical words are embedded in a sentence. Finally, this "nothing but lexical association" account would predict no N400 reduction for the final words of sentences such as "The game was called when it started to lightning" or "Our guests should be arriving shortly", as they include no lexical associates. Yet the N400s to the final words of such sentences are reduced relative to low cloze endings that are in no way related to the expected best completions of the sentences in which they occur.[7]

Unrelated low cloze probability endings also elicit a frontally distributed late positivity subsequent to the N400 peak (see Fig. 1). A positivity with a frontal maximum observed in a variant of the "oddball" task[8] was considered by Courchesne, Hillyard and Galambos (1975) to be a "novelty" response. However, response to "novelty" seems an unlikely explanation for the present data, as a similar positivity was not observed in a variant of this design which included semantically anomalous endings that were or

[7]While we think that such sentences are associated with reduced N400s, we cannot be certain if this is the case for every such sentence individually, as the ERPs are based on averages across trials. An experiment including sentences with and without lexical associates in a controlled fashion would clearly be worth doing.

[8]This task included not only frequently occurring "standard" stimuli and less frequently occurring "target" stimuli that had to be responded to, but also a set of infrequently occurring "novel" stimuli that were never repeated and which required no response from the subject.

were not related to their sentences' expected completions (Kutas et al., 1984); *a priori* these endings would seem to be just as novel as the low cloze endings, if not more so.

Perhaps this late positivity actually reflects activity in the frontal cortex.[9] Continuing to speculate in this vein, in a series of positron emission tomography (PET) studies, Frith and his colleagues (Friston, Frith, Liddle, & Frackowiak, 1991; Frith, Friston, Liddle, & Frackowiak, 1991; Wise et al., 1991) have posited an inhibitory interaction between the frontal and temporal areas during word processing. They proposed that successful intrinsic word generation[10] is based on inhibitory modulation of the network of activated (via automatic spreading activation) stored word representations in the superior temporal areas by the left prefrontal cortex. A similar inhibitory mechanism might be needed to explain how it is that we can readily interpret an unexpected but congruent ending; on this view, the left prefrontal cortex supports contextual integration of the low cloze ending by inhibiting the activated representation of the ending primed by the sentence context. The engagement of this inhibitory process in the left prefrontal cortex is indexed by the frontal positivity to low cloze endings, which is in fact more marked over the left hemisphere in these data. A similar mechanism would not be expected for truly anomalous endings, as these cannot be interpreted. Halgren and his colleagues (Halgren, 1990; Halgren & Smith, 1987) have also invoked an inhibitory background process following a period of excitation encouraging divergent associations that " . . . would cause only those elements receiving convergent excitation to remain activated"; they linked this inhibitory process with a positivity (in their case with a centroparietal maximum). They hypothesise that this cycle of associative activation and inhibition is a prerequisite for integrating a word's meaning with a sentence context.[11]

The presence of N400 components in the ERPs to words occurring in unstructured lists, as well as to target words in lexical decision, categorisation and verification tasks, is well documented (Bentin, 1987; Bentin et al., 1985; Boddy, 1986; Fischler et al., 1983; 1984; 1985; Harbin et al., 1984; Holcomb, 1988; Holcomb & Neville, 1990). Thus on this count, the present data corroborate previous reports and extend them to a word-pair

---

[9]Note that we realise this proposition is hypothetical, and that without supporting converging evidence it would be presumptuous to assume that because the potential is largest frontally it must be generated in the frontal cortex.

[10]The subjects were asked either to generate as many words as they could starting with a certain letter or that fell under a certain semantic category.

[11]Note that these two accounts differ primarily in that the N4/P3 in Halgren's model is presumed to be generated bilaterally in the hippocampal formation and various association cortices and to be characteristic of every sentence.

task that does not entail a decision coincident with the priming manipulation; the latter is important to get an estimate of the scalp distribution of the N400 effect *per se*. And, indeed, the N400s to the second words of the pairs in this study are not contaminated by any significant late positivity, but nonetheless still mirror variations in the degree of semantic relations (see also Kutas & Hillyard, 1989). Moreover, unlike some of the studies wherein N400 distributions were confounded by overlapping decision-related components, the N400 to word pairs in the current study has the posterior distribution that is characteristic of N400s in sentences. In relative terms, whether or not a word has been preceded by a semantically associated word in the word-pair task is reflected in the amplitude of the ERPs elicited. ERPs to words preceded by a semantically related word yield ERPs with a slightly larger P2 (possibly because of less N400 overlap) and a significantly smaller N400 than words which followed semantically unrelated words. In summary, all second words in the letter search word-pair task contain N400s; their amplitudes, however, vary with semantic association.

Since the ERP data from the word-pair and sentence tasks were collected in the same subjects, we can address the question of the similarity of the sentential and lexical context effects on the N400 more cleanly than has been possible heretofore.[12] Even a cursory look reveals a striking similarity in the ERPs in the word-pair and sentence conditions, especially for the unrelated pairings. In both conditions, the ERPs to the critical words are characterised by a large negative component (N400) that is larger over posterior than anterior sites and slightly larger over the right than the left hemisphere.[13] Moreover, in both conditions, N400 amplitudes are a function of the strength of semantic relation or association between the context and the eliciting word: the greater the strength of association, the smaller the associated N400. In short, following both single-word and sentential

[12]Comparisons in the set same of subjects help overcome the substantial individual subject variabilities in the waveshapes and amplitudes of the ERPs elicited by words. In fact, it is for this reason that so many ERP experiments focus on the difference in the ERPs between two or more experimental conditions instead of on the actual waveforms. For often the relative effect of an experimental manipulation is more robust and less variable than the raw waveforms used to derive the difference ERPs; which is, of course, not to deny that there are individual differences even in the size, distribution and latencies of ERP relatedness effects. Moreover, even the present comparison is imperfect in that the task requirements for the word-pair and sentence context conditions are different. Note, however, that since the letter search task can only be performed after the word pairs have been presented, the subject's primary task during the actual presentation of the word pairs is reading and remembering, much like it is in the sentence task.

[13]While it is likely that the ERP between 300 and 600 msec comprises more than one generator (component), the discussion here focused on the large negativity with a maximum over midline parietal sites.

contexts, the ERP semantic context effect (N400 difference wave) is a monophasic negativity with a parieto-occipital maximum at the scalp.

The most striking difference between the N400 effect in the two context conditions is the substantially larger effect for sentences than word pairs. In fact, the overwhelming difference in the size of these two N400 effects on visual inspection tends to obscure possible differences between them, such as in latency or scalp distribution (see Fig. 3, left-hand column). However, when the amplitudes of the N400 difference ERPs in the two conditions are equated (as in the right-hand column of Fig. 3), the equivalence of the first 200 msec of their distributions over the scalp is conspicuous. Although it may be argued that the word-pair ERPs appear to contain a larger N400 peak at the frontal sites, this distributional difference is more apparent than real. This is because the N400 effect in the sentence condition is contaminated by a frontally distributed late positivity elicited by unrelated low cloze probability endings. Specifically, the initial phase of this frontal positivity to sentence endings coincides with the final phases of the N400, thereby abbreviating the N400 at frontal sites and making it appear smaller. With this difference accounted for, neither the morphology nor the scalp distribution of the N400 difference waves reveals the nature of the context that preceded it. From this, we conclude that the nature of the operation indexed by the N400 difference is essentially the same under the two context conditions.

Equating the amplitudes of the N400 effects in the two experimental context conditions also makes it easier to see the small but significant difference in their onset latencies: the N400 difference ERP begins approximately 30–50 msec earlier for critical words that terminate sentences than for second words in word pairs. As there is little if any difference between the latencies of the N400s to unrelated words in the word-pair condition and the N400s to low cloze probability endings in the sentence condition, it follows that the latency difference must emanate from differential responses to the related words and high cloze probability endings. And, indeed, almost all of the difference in N400 latency can be ascribed to the large and early positivity elicited by high cloze probability endings in the sentence condition. In marked contrast to the ERPs to the two low cloze probability endings, those to the high cloze endings are characterised by an enhanced positivity starting as early as 200 msec post-stimulus and lasting throughout the recording epoch. In fact, an examination of the raw waveforms reveals that most of the ERP difference between the effects of word-pair and sentence contexts both in latency and in amplitude is due to the contribution of the ERPs to the highly constrained sentence endings. In short, the earlier onset of the sentential N400 effect is a consequence of the differential processing (presumably facilitatory) accorded the high cloze probability endings and not of the slowed or differential processing of unexpected or unrelated words.

So, what can we infer from this data pattern? Although not identical, semantic context affects ERPs in a strikingly similar fashion whether the context is an immediately preceding word or a sentence fragment. In so far as there are any significant differences in either the onset latency, amplitude or duration of these N400 context effects, they appear to be *quantitative* and not *qualitative* in nature. The pattern of results is thus most consistent with the view that the same underlying processes are invoked (at least in the initial phase), albeit to differing extents and with somewhat different time-courses in the two context conditions.

Both the lexical and sentential N400 context effects can readily be accommodated by the view that what has been varied is contextual constraint, and that the more stringent the constraints, the smaller the associated N400. Thus, the N400 effect is larger for words in sentences than in word pairs because the high cloze probability endings are more constrained by their contexts than are the highly related words in their pairings. This explanation, coupled with the fact that the reading task directs more attention to a word's meaning than does the letter search task, may explain most of the present observations.

The influence of attention on the N400 effect is well-documented. The results of several studies show that N400 effects are larger when attention is directed at semantic relationships than when they are not; in fact, some attention may be necessary for the effect to appear (e.g. Bentin, Kutas & Hillyard, in press; Brown & Hagoort, 1993; Holcomb, 1988; Kutas & Van Petten, 1988; Nobre & McCarthy, pers. comm.) Thus, it may be reasonable to attribute some of the difference in N400 amplitude between lexical and sentential context conditions to the attention paid to meaning. Certainly, the letter search task could have been performed by someone who did not know what the words meant, whereas sentence comprehension entailed semantic analysis.

However, it is easier to take issue with the proposition that the N400 effects reflect a sensitivity to different types and degrees of contextual constraints. This criticism arises in part from a general discontent with the very slow presentation rates employed in ERP studies of sentence processing. In the present study, the slow rate of presentation for words in sentences of such high levels of contextual constraint could arguably have led to abnormal processing strategies that may have had little to do with normal on-line processing. Specifically, it has been suggested that the ERP context effects might not reflect degree of contextual constraint (congruence) but rather the degree of disconfirmation of a situation-specific prediction. On this view, the slow rate of presentation and high constraint may promote prediction-making of sentence-final words, with the resulting N400 amplitude reflecting the distance between the ending presented and the self-generated ending. This particular scenario can be ruled out by the

finding of Kutas and Hillyard (1984) that the amplitude of the N400 is determined by a word's cloze probability rather than by a mismatch between the presented and expected endings. In the absence of an explicit attempt to dissociate cloze probability and contextual constraint, the two factors are generally correlated; however, the two factors are dissociable such that a word can have a low cloze probability because it is unconstrained by its natural context (e.g. "They went to see the famous clown") or because an experimenter has violated the natural expectancy (e.g. "He mailed the letter without a thought"). Kutas and Hillyard (1984) crossed several levels of contextual constraint with several levels of cloze probability and showed that the amplitude of the N400 to a low cloze probability ending ($P < 0.05$) was the same whether the word completed a sentence of high, medium or low constraint.

A more compelling argument about the extent to which the present results are an artifact of the abnormally slow presentation rate would be to compare the pattern of results for the same set of sentences presented at different rates including one that approximates normal reading. The ERPs presented in Fig. 4 show just such a comparison for sentences presented at rates of one word every 100, 250, 700 and 1150 msec; represented are grand average ERPs (across 9 or 10 subjects each) of the final words of the same set of sentences used in the present study sorted according to ending type. Each subject read 320 sentences, a different subset of 160 sentences at each of two different rates. These data demonstrate that one aspect of the pattern of effects observed in the present study—namely, the large N400 to endings unrelated to the best completions, the most positive response to the best completions, and the intermediate amplitude N400 to endings that were related to the best completions—is not a function of the presentation rate. It is seen even when words were presented at a rate of 10 per second. It is highly unlikely that at a rate of 10 words/sec or even at 4 words/sec (close to normal reading rate), the subjects were actively predicting the sentence-final words. Thus, these data also argue against the view that the amplitude of the N400 reflects degree of mismatch between a predicted and the actual ending. Not only is the relative pattern of congruity effects similar across the conditions, but as shown in the difference ERPs (unrelated endings minus best completions) in Fig. 5, the amplitude of the context effect is equivalent for three of the rates (100, 250 and 1150 msec) and only slightly larger when the SOA between words is 700 msec; the N400 does not get larger the more time subjects have to predict the sentence-final word (i.e. 700 msec *vs* 1150 msec SOA condition). Otherwise, the only amplitude difference is in response to the best completions in the 700 msec SOA condition, which do show a slightly larger positivity around 200 msec post-stimulus (at posterior sites only). This latter effect might account for the slightly earlier effect for the

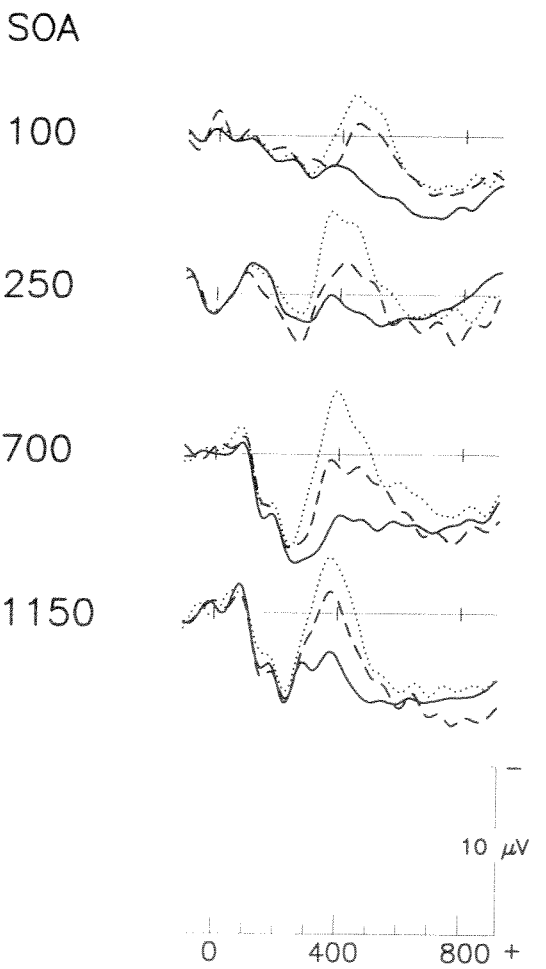

FIG. 4 Comparison of the grand average ERPs elicited by sentence-final words presented at four different rates. The ERPs to the high cloze probability endings or best completions (solid line), low cloze probability endings semantically related to the best completions (dashed line) and the low cloze probability endings that were unrelated to the best completions (dotted line) are superimposed. From top to bottom the stimulus onset asynchrony (SOA) between words at the four different rates was 100, 250, 700 and 1150 msec, respectively; each word was flashed for a duration of 50 msec. Each ERP is an average across 9 or 10 subjects; each subject experienced sentences at two different rates. All recordings are from the midline parietal (Pz) electrode.

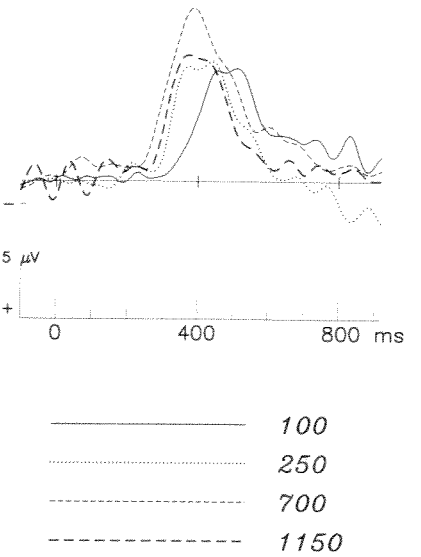

FIG. 5 Difference ERPs generated by subtracting the ERPs to best completions from ERPs to endings that are unrelated to the best completions. Overlapped are the difference ERPs from four different SOA conditions. All recordings are from the parietal recording site.

sentences than the word pairs in the present experiment, thereby eliminating the 30 msec latency difference between the two. With this latency difference eliminated, the lexical and sentential context ERP effects in the present experiment would be identical in their onset latencies.

Finally, the parameter of the ERP that is most altered by the varying rates of presentation is latency. Both the onset and peak latencies of the N400 effect appear to be inversely related to presentation rate. The differences among the 250, 700 and 1150 msec SOA conditions are quite small (less than 30 msec). By contrast, the N400 effect for sentences presented at a rate of 10 per second is delayed by between 80 and 100 msec (see also Kutas, 1987; Kutas & Van Petten, 1990).[14] Note first that the N400 effect for word pairs presented with 0 SOA between prime and target

[14]A subset of these data, specifically the grand averages for the best completion and unrelated low cloze probability endings at the rates per word of 100 msec (n = 9), 250 msec (n = 7), 700 msec (n = 10) and 1150 msec (n = 9), were presented by Kutas and Van Petten (1990). The data presented in the present paper include a few more subjects as well as the ERPs to the low cloze probability endings that are semantically related to the sentence's best completion. A different subset of the data, including the nine subjects in the 100 msec SOA condition, of whom four were also in the 700 msec condition, were reported in Kutas (1987).

is likewise delayed in latency and that mean reaction times are also slowed when the SOA between primes and targets is shortened or words in a sentence are presented at rates faster than normal reading (e.g. Balota, Black, & Cheney, 1992; De Groot, 1984; Favreau & Segalowitz, 1983; Fischler & Bloom, 1980; Neely, 1977; Till, Mross, & Kintsch, 1988; Van Petten & Kutas, 1987). Again, these data provide no evidence that the semantic context effects attributed to variations in contextual constraint are an artifact of the slow presentation rate. In summary, these ERP data demonstrate a remarkable similarity between lexical and sentential context effects, thereby questioning the need to invoke distinct mechanisms.

Manuscript received April 1992
Revised manuscript received June 1993

REFERENCES

Allison, T., Wood, C.C., & McCarthy, O. (1986). The central nervous system. In M.G.H. Coles, E. Donchin, & S. Porges (Eds), *Psychophysiology: Systems, processes and applications*, pp. 5–25. New York: Guilford Press.

Balota, D.A., & Chumbley, J.I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 340–357.

Balota, D.A., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraints and parafoveal visual information in reading. *Cognitive Psychology, 17*, 364–390.

Balota, D.A., Flores d'Arcais, G.B., & Rayner, K. (Eds) (1990). *Comprehension processes in reading*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Balota, D.A., Black, S.R., & Cheney, M. (1992). Automatic and attentional priming in young and older adults: Reevaluation of the two-process model. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 485–502.

Battig, W.F., & Montague, W.E. (1969). Category norms for verbal items in 56 categories: A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology, Monograph, 80*, 1–44.

Bentin, S. (1987). Event-related potentials, semantic processes, and expectancy factors in word recognition. *Brain and Language, 31*, 308–327.

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

Bentin, S., Kutas, M., & Hillyard, S.A. (1993). Electrophysiological evidence for task effects on semantic priming in auditory word processing, *Psychophysiology, 30*, 161–169.

Besner, D., & Humphreys, G.W. (Eds) (1991). *Basic processes in reading: Visual word recognition*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Besson, M., & Macar, F. (1987). An event-related potential analysis of incongruity in music and other non-linguistic contexts. *Psychophysiology, 24*, 14–25.

Bloom, P.A., & Fischler, I. (1980). Completion norms for 329 sentence contexts. *Memory and Cognition, 8*, 631–642.

Boddy, J. (1986). Event-related potentials in chronometric analysis of primed word recognition with different stimulus onset asynchronies. *Psychophysiology, 23*, 232–245.

Boddy, J., & Weinberg, H. (1981). Brain potentials, perceptual mechanism and semantic categorization. *Biological Psychology, 12*, 43–61.

Brown, C.M., & Hagoort, P. (in press). The processing nature of the N400: Evidence from masked priming, *Journal of Cognitive Neuroscience, 5*, 34–44.

Carroll, P., & Slowiaczek, M.L. (1986). Constraints on semantic priming in reading: A fixation time analysis. *Memory and Cognition, 14*, 509–522.

Courchesne, E., Hillyard, S.A., & Galambos, R.G. (1975). Stimulus novelty, task relevance, and the visual evoked potential in man. *Electroencephalography and Clinical Neurophysiology, 39*, 131–143.

Dale, A., & Sereno, M. (1993). Improved localization of cortical activity by combining EEG and MEG with RIM cortical surface reconstruction: A linear approach. *Journal of Cognitive Neuroscience, 5*, 162–176.

De Groot, A.M.B. (1984). Primed lexical decision: Combined effects of the proportion of related prime–target pairs and the stimulus onset asynchrony. *Quarterly Journal of Experimental Psychology, 36A*, 253–280.

De Groot, A.M.B. (1985). Word-context effects in word naming and lexical decision. *Quarterly Journal of Experimental Psychology, 37A*, 281–297.

Den Heyer, K., Briand, K., & Dannenbring, G.L. (1983). Strategic factors in a lexical decision task: Evidence for automatic and attentional-driven processes. *Memory and Cognition, 11*, 374–381.

Duffy, S.A., Henderson, J.A., & Morris, R.K. (1989). Semantic facilitation of lexical access during sentence processing. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 791–801.

Favreau, M., & Segalowitz, N.S. (1983). Automatic and controlled processes in first- and second-language reading of fluent bilinguals. *Memory and Cognition, 11*, 565–574.

Fischler, I., & Bloom, P.A. (1979). Automatic and attentional processes in the effects of sentence contexts on word recognition. *Journal of Verbal Learning and Verbal Behavior, 18*, 1–20.

Fischler, I., & Bloom, P.A. (1980). Rapid processing of the meaning of sentences. *Memory and Cognition, 8*, 216–225.

Fischler, I., Bloom, P.A., Childers, D.G., Roucos, S.E., & Perry, N.W., Jr (1983). Brain potentials related to stages of sentence verification. *Psychophysiology, 20*, 400–409.

Fischler, I., Bloom, P.A., Childers, D.G., Arroyo, A.A., & Perry, N.W. (1984). Brain potentials during sentence verification: Late negativity and long-term memory strength. *Neuropsychologia, 22*, 559–568.

Fischler, I., Childers, D.G., Achariyapaopan, T., & Perry, N.W., Jr (1985). Brain potentials during sentence verification: Automatic aspects of comprehension. *Biological Psychology, 21*, 83–106.

Fodor, J.A. (1983). *Modularity of mind*. Cambridge, MA: MIT Press.

Forster, K.I. (1981). Priming and the effects of sentence and lexical contexts on naming time: Evidence for autonomous lexical processing. *Quarterly Journal of Experimental Psychology, 33A*, 465–495.

Foss, D.J. (1982). A discourse on semantic priming. *Cognitive Psychology, 14*, 590–607.

Friston, K.J., Frith, C.D., Liddle, P.F., & Frackowiak, R.S.J. (1991). Investigating a network model of word generation with positron emission tomography. *Proceedings of the Royal Society of London, B244*, 101–106.

Frith, C.D., Friston, K.J., Liddle, P.F., & Frackowiak, R.S.J. (1991). A PET study of word finding. *Neuropsychologia, 29*, 1137–1148.

Halgren, E. (1990). Insights from evoked potentials into the neuropsychological mechanisms of reading. In A.B. Scheibel & A.F. Wechsler (Eds), *Neurobiology of higher cognitive function*, pp. 103–149. New York: Guilford Press.

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

Harbin, T.J., Marsh, G.R., & Harvey, M.T. (1984). Differences in the late components of the event-related potential due to age and to semantic and non-semantic tasks. *Electroencephalography and Clinical Neurophysiology, 59*, 489–496.

Henderson, L. (1982). *Orthography and word recognition in reading*. London: Academic Press.

Hillyard, S.A., & Picton, T.W. (1987). Electrophysiology of cognition. In F. Plum (Ed.), *Handbook of physiology. Section 1: The nervous system. Vol. V: Higher functions of the brain*, pp. 519–584. Washington, DC: American Physiological Society.

Holcomb, P.J. (1988). Automatic and attentional processing: An event-related brain potential analysis of semantic processing. *Brain and Language, 35*, 66–85.

Holcomb, P.J., & Neville, H.J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Language and Cognitive Processes, 5*, 281–312.

Holcomb, P.J., & Neville, H.J. (1991). Natural speech processing: An analysis using event-related brain potentials. *Psychobiology, 19*, 286–300.

Kutas, M. (1987). Event-related brain potentials (ERPs) elicited during rapid serial visual presentation of congruous and incongruous sentences. In R. Johnson Jr, J.W. Rohrbaugh, & R. Parasuraman (Eds), Current trends in event-related brain potential research. *Electroencephalography and Clinical Neurophysiology* (suppl. 40), 406–411.

Kutas, M., & Hillyard, S.A. (1980a). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207*, 203–205.

Kutas, M., & Hillyard, S.A. (1980b). Reading between the lines: Event-related brain potentials during natural sentence processing. *Brain and Language, 11*, 354–373.

Kutas, M., & Hillyard, S.A. (1980c). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology, 11*, 99–116.

Kutas, M., & Hillyard, S.A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition, 11*, 539–550.

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. (1989). An electrophysiological probe of incidental semantic association. *Journal of Cognitive Neuroscience, 1*, 38–49.

Kutas, M., & Kluender, R. (in press). What is who violating? A reconsideration of linguistic violations in light of event-related potentials. In H.J. Heinze, T. Münte, & G.R. Mangun (Eds), *Cognitive Electrophysiology*. Boston: Birkhauser.

Kutas, M., & Van Petten, C. (1988). Event-related brain potential studies of language. In P.K. Ackles, J.R. Jennings, & M.G.H. Coles (Eds), *Advances in psychophysiology*, Vol. 3. Greenwich, CT: JAI Press.

Kutas, M., & Van Petten, C. (1990). Electrophysiological perspectives on comprehending written language. In P.M. Rossini & F. Mauguiere (Eds), New trends and advanced techniques in clinical neurophysiology. *Electroencephalography and Clinical Neurophysiology* (suppl. 41), 155–167.

Kutas, M., Lindamood, T., & Hillyard, S.A. (1984). Word expectancy and event-related brain potentials during sentence processing. In S. Kornblum & J. Requin (Eds), *Preparatory states and processes*, pp. 217–238. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Kutas, M., Neville, H.J., & Holcomb, P.J. (1987). A preliminary comparison of the N400 response to semantic anomalies during reading, listening, and signing. In R.J. Ellingson, N.M.F. Murray, & A.M. Halliday (Eds), The London Symposia. *Electroencephalography and Clinical Neurophysiology* (suppl. 39), 325–330.

Kutas, M., Van Petten, C., & Besson, M. (1988). Event-related potential asymmetries during the reading of sentences. *Electroencephalography and Clinical Neurophysiology, 69*, 218–233.

Masson, M.E.J. (1986). Comprehension of rapidly presented sentences: The mind is quicker than the eye. *Journal of Memory and Language, 25*, 588–604.

McCallum, W.C. (1988). Potentials related to expectancy, preparation and motor activity. In T.W. Picton (Ed.), *Human event-related potentials: Handbook of electroencephalography and clinical neurophysiology*, revised edn, Vol. 3, pp. 427–534. Amsterdam: Elsevier.

McCallum, W.C., Farmer, S.F., & Pocock, P.K. (1984). The effects of physical and semantic incongruities on auditory event-related potentials. *Electroencephalography and Clinical Neurophysiology, 59*, 477–488.

Meyer, D.E., & Schvaneveldt, R.W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227–234.

Neely, J. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106*, 226–254.

Neely, J.H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. Humphreys (Eds), *Basic processes in reading: Visual word recognition*, pp. 264–336. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*, 97–113.

O'Seaghdha, P.G. (1989). The dependence of lexical relatedness effects on synactic connectedness. *Journal of Experimental Psychology: Language, Memory and Cognition, 15*, 73–87.

Polich, J., Vanasse, L., & Donchin, E. (1981). Category expectancy and the N200. *Psychophysiology, 18*, 142 (abstract).

Postman, L., & Keppel, G. (1970). *Norms of word association*. New York: Academic Press.

Schwanenflugel, P.J. (1991). Contextual constraint and lexical processing. In G.B. Simpson (Ed.), *Understanding word and sentence*, pp. 23–45. Amsterdam: North-Holland.

Seidenberg, M.S. (1990). Lexical access: Another theoretical soupstone? In D.A. Balota, G.B. Flores d'Arcais, & K. Rayner (Eds), *Comprehension processes in reading*, pp. 33–72. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Seidenberg, M.S., Tanenhaus, M.K., Leiman, J.M., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology, 14*, 489.

Seidenberg, M.S., Waters, G.S., Sanders, M., & Langer, P.L. (1984). Pre- and postlexical loci of contextual effects on word recognition. *Memory and Cognition, 12*, 315–328.

Simpson, G.B. (Ed.) (1991). *Understanding word and sentence*. Amsterdam: North-Holland.

Simpson, G.B., Peterson, R.R., Casteel, M.A., & Burgess, C. (1989). Lexical and sentence context effects in word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 88–97.

Stanovich, K.E., & West, R.F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General, 112*, 1–36.

Swinney, D.A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior, 18*, 645–659.

Tabossi, P. (1991). Understanding words in context. In G.B. Simpson (Ed.), *Understanding word and sentence*, pp. 23–45. Amsterdam: North-Holland.

Till, R.E., Mross, E.F., & Kintsch, W. (1988). Time course of priming for associate and inference words in a discourse context. *Memory and Cognition, 16*, 283–298.

Van Petten, C., & Kutas, M. (1987). Ambiguous words in context: An event-related potential analysis of the time course of meaning activation. *Journal of Memory and Language, 26*, 188–208.

Van Petten, C., & Kutas, M. (1991a). Interactions between sentence context and word frequency in event-related brain potentials. *Memory and Cognition, 18*, 380–393.

Van Petten, C., & Kutas, M. (1991b). Influences of semantic and syntactic context on open and closed class words. *Memory and Cognition, 19*, 95–112.

Van Petten, C., & Kutas, M. (1991c). Electrophysiological evidence for the flexibility of lexical processing. In G. Simpson (Ed.), *Understanding word and sentence*, pp. 129–184. Amsterdam: North-Holland.

West, R.F., & Stanovich, K.E. (1982). Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 8*, 385–399.

Wise, R., Chollet, F., Hadar, U., Friston, K., Hoffner, E., & Frackowiak, R. (1991). Distribution of cortical neural networks involved in word comprehension and word retrieval. *Brain, 114*, 1803–1817.

APPENDIX 1

Sentences used in the experiment. The experimental condition to which each sentence belongs is indicated following each sentence as follows: BC for best completions or the high cloze probability endings; R for low cloze probability endings that were semantically related to best completions (given in parentheses); and U for low cloze probability endings that were semantically unrelated to the best completions.

Every Monday the gardener mows the lawn. BC
She put on her high heeled boots (shoes). R
The police towed the car sitting in front of the no parking sign. BC
The cub scouts needed a new den chair (mother). U
At the ice cream parlor Jane ordered a chocolate sundae. BC
He had to fill the car's radiator with water. BC
The pigs wallowed in the mud. BC
Ray fell down and skinned his knees. BC
The halftime entertainment was the junior high marching band. BC
During the volley someone stepped on Joe's watch (foot). U
The pizza was too hot to chew (eat). R
The paint turned out to be the wrong consistency (color). U
He lay down and went to sleep. BC
The wild birds at the zoo are kept in captivity (cages). R
The racing cars received the checkered flag. BC
The ship disappeared into the thick mist (fog). R
That pencil is so blunt it needs to be sharpened. BC
A pacemaker was needed to repair his failing heart. BC
There are two pints in a quart. BC
Nothing can beat a bowl of hot broth (soup). R
All the guests had a very good excuse (time). U
Father carved the turkey with an electric knife. BC
The dirty clothes were piled up in the laundry hamper (basket). R
Joe stood up and the canoe tipped over. BC
The TV was so loud that he couldn't hear himself think. BC
It's hard to admit when one is asleep (wrong). U
The package should be mailed at the post office. BC
The mail should get here very shortly (soon). R
The American flag is red, white and blue. BC
She's afraid of deep water because she can't see (swim). U

The waitress rang the bill on the cash register. BC
One of the scouts did not know the way and got hurt (lost). U
Even for an amateur he was pretty good. BC
The rainstorm was followed by a beautiful rainbow. BC
Jean hurriedly shoved her way through the crowd. BC
The mother fed the newborn infant (baby). R
At first the woman refused but she changed her clothes (mind). U
She was docked one hour's pay for coming to work drunk (late). U
They heated the pool with solar power (energy). R
The baby weighed six pounds at noon (birth). U
I added my name to the top of the wall (list). U
My youngest son just graduated from high school. BC
December is the last month of the year. BC
The fertilizer enriched the stink (soil). U
Our guests should be arriving hungry (soon). U
The clerk put the groceries in the shopping carts (bags). R
On top of the hamburger there was melted cheese. BC
The children went outside to shower (play). U
The game was called when it started to lightning (rain). R
My cat is covered with white fur. BC
The prisoners were planning their picnic (escape). U
He disappeared last year and has not been seen. BC
The teacher wrote the problem on the board. BC
The basketball players were all over six feet tall. BC
Lois is taller than most girls of her age. BC
The rude waiter was not left a big clientele (tip). U
The policeman's gun was sitting in his shoulder holster. BC
The office held a new year's eve bash (party). R
He wondered if the storm had done much harm (damage). R
Next year my little son will be going to college (school). R
They went as far as they dared (could). U
Mary looked at her watch to check the band (time). U
The dough was put in the hot oven. BC
He scraped the cold food from the dinner platter (plate). R
Larry made a full pot of tea (coffee). R
George had been fired but he couldn't tell his staff (wife). U
The mole lived in a hole in the pipe (ground). U
The bathroom faucet sprung a leak. BC
Al wrote her a love note (letter). R
The bad boy was sent to his counselor (room). U
They took their dirty clothes to a dry cleaners. BC
The butler hung their clothes in the closet. BC
When the shooting started they ran for help (cover). U
The barbells the strong man lifted were very rusty (heavy). U
The summer was so hot they decided to install an outdoor pool. BC
He studied a long time so he would pass his tests (exams). R
The surprise party made him feel very happy. BC
The parking lot was full of expensive foreign autos (cars). R
They sat together without speaking a single syllable (word). R
Cathy is liked by all her friends. BC
Autumn is a good time to buy some new clothes. BC
He went to the factory where the toys were designed (made). R

Abby brushes her teeth after every meal. BC
Phil put some drops in his eyes. BC
His boss refused to give him a car (raise). U
The doctor told him he had high blood sugar (pressure). U
The bird built a nest in which she could lay her eggs. BC
They raised pigs on their ranch (farm). R
In the first space enter your last address (name). R
He has trouble adding and subtracting large numbers. BC
Dillinger once robbed that train (bank). U
She seasoned the steak with black pepper. BC
He looked up the misspelled word in the index (dictionary). U
The better students thought the test was too simple (easy). R
She called her husband at his convenience (office). U
On hot days many people sun themselves on the roof (beach). U
John was so exhausted he took a vacation to get some help (rest). U
It's easy to get lost without a map. BC
William went to the bank to borrow some cash (money). R
He made a holster for his father (gun). U
The milk was left out of the refrigerator and turned yellow (bad). U
The sink was clogged so they called a handyman (plumber). R
John poured himself a glass of sparkling red wine. BC
The piano was out of tune. BC
Janes's new outfit made her the center of attention. BC
Fred put the worm on the table (hook). U
Sacramento is the state capitol of California. BC
Jason called directory assistance for the telephone repairman (number). U
Before exercising Jack always stretches his muscles. BC
His wealthy parents enrolled him in a private academy (school). R
Vic asked her to repeat what she had said. BC
The movers put the sofa on the bare ground (floor). R
His leaving home amazed all his friends. BC
The theatre ushers walked up and down the rows (aisles). R
Most folks see the koala bears at the San Diego zoo. BC
Cut me a slice of bread from that loaf. BC
Bill jumped in the lake and made a big splash. BC
It's raining and I forgot my coat, hat and keys (umbrella). U
Jack decided to wear a three piece suit. BC
He was horrified to receive a letter from the Internal Revenue Service. BC
The whole town came to hear the mayor resign (speak). U
They left the dirty dishes in the bedroom (sink). U
He had to wake up early to get there on schedule (time). R
Pete won the cross country race. BC
They ate ice cream and cake at his birthday celebration (party). R
Jill opened the gate in the white picket fence. BC
I could not remember his last name (mistake). U
The horse collapsed right after winning the race. BC
The exit was marked by a large sign. BC
Shuffle the cards before you leave (deal). U
Sally fell in the water and was dripping wet. BC
Each night the campers built a huge blaze (fire). R
The grocer checked his stock before going out. BC
Tim put his feet up on his father's oak chair (desk). R

Jean was glad the affair was finished (over). R
The tenants were evicted when they did not pay the last month's bill (rent). R
The wet towels were hung on the line to air (dry). R
Jock bet all he had on the last horse race. BC
He took the money from his leather vest (wallet). U
The tickets for the opening concert were sold privately (out). U
The soldier complained that his portion was too little (small). R
The children were outside playing cowboys and Indians. BC
The movie was so crowded they could not find a single chair (seat). R
Betsy could never tell a soul (lie). U
Fred realized the old house was up for auction (sale). R
Cathy was glad that Friday was payday because she was poor (broke). R
Jan tried to squeeze in but there was no room. BC
George made out a check to pay the monthly telephone fee (bill). R
The important papers were locked in a vault (safe). R
The boys played marbles and the girls jumped happily (rope). U
The sharpened pencils are in the top desk drawer. BC
The businessman took the receipts and checks to the teller (bank). R
While skiing Randy broke his arm (leg). R
The addict was caught pushing illegal movies (drugs). U
As soon as they got in they turned off the porch lamp (lights). R
George kept his pet on a diet (leash). U
Jon swept the floor with a mop (broom). R
You can't open the door with the wrong key. BC
He mailed the letter without a thought (stamp). U
He crept into the room without a sound. BC
Jeff felt sorry but it was not his turn (fault). U
Through the rain it was hard to read the signals (signs). R
The girl knew most of the words for her spelling quiz (test). R
They asked Dave to play tennis but he was too good (tired). U
When you leave please close the paper (door). U
Karen awoke after a bad hangover (dream). U
The largest city in England is London. BC
Bees use the nectar of flowers to make honey. BC
The sun turned his hair blond (dry). U
He sanded the wood until it was smooth. BC
He hung the picture on the living room wall. BC
The young boy punted the football. BC
In the morning Jim woke up and jumped out of his bed. BC
He shouted at the top of his stairs (lungs). U
The tenants decided to take their landlord to lunch (court). U
They're out in the garden pulling roots (weeds). R
The child learned to count to ten. BC
That train is never on time. BC
They went to pick up their parents at the railway depot (station). R
She sewed the button on with needle and black string (thread). R
We stopped at the water fountain to get a sip (drink). R
The sprinter ran the last quarter mile. BC
He was stung by a wasp (bee). R
He heard a knock at the front entrance (door). R
Joan boiled the eggs in minutes (water). U
The power went out and all of the ice melted. BC

The attendant filled the car with fuel (gas). R
The doctor stuck the thermometer in her mouth to check her temperature. BC
To keep the dogs out of the yard he put up a fence. BC
The driver of the speeding car was given a citation (ticket). R
The president lives in the White House. BC
The teller cashed the large traveller's check. BC
Three people were killed in a major highway crash (accident). R
A dog has a good sense of loyalty (smell). U
In the old West stagecoaches were pulled by stallions (horses). R
In the morning he forgot to take his vitamin pill. BC
She went to the salon to color her toes (hair). U
I like hot fudge with ice cream. BC
Brian poured some sauce on his rare meat (steak). U
When the power went out the house became dark. BC
She was named after her conversion (mother). U
Every Sunday morning people pray in their local congregation (church). R
There are several roller coasters in that amusement park. BC
He was so frightened he was as white as a ghost. BC
The final grades were posted on the bulletin board. BC
Sam could not believe her story was true (told). U
Tim threw a rock and broke the glass (window). R
The lecture should last about one hour. BC
The doctor set the man's broken leg in a splint (cast). R
I would like thousand island dressing on my salad. BC
To pay for the car Al simply wrote a check. BC
We sprayed the yard to keep away the skunks (bugs). U
He hung her coat in the back (closet). U
The lawyer feared that his client would be found crazy (guilty). U
New York is a very busy town (city). R
He bought a wall to wall bed (carpet). U
The gas station is about two miles down the path (road). R
He can run the mile in under four minutes. BC
Be careful because the top of the stove is very cluttered (hot). U
John filled the pen with care (ink). U
Water and sunshine help plants to grow. BC
The children held hands and formed a ring (circle). R
It's unlucky to walk under a ladder. BC
The fire engine raced down the main street (road). R
For graduation Jim received a pen and pencil set. BC
Don't believe everything you suspect (hear). U
A female chicken is called a hen. BC
At parks we frequently ride the roller coaster. BC
He loosened the tie around his neck. BC
None of his books made much sense (money). U
He put a clean sheet on the clipboard (bed). U
The defendant pleaded not guilty by reason of insanity. BC
The parents pleaded with their daughter to come quietly (home). U
He went to UCSD for four years to get his bachelor's degree. BC
Children learn to read and write in the first grade. BC
The paint spilled onto the tile floor. BC
During the movie we ate buttered popcorn. BC
When the two met one of them held out his ID (hand). U

The boat passed easily under the falls (bridge). U
My uncle kissed my mother and gave her a big hug. BC
He finally decided to shingle the damaged roof. BC
The picnic was ruined by the downpour of showers (rain). R
Most cats can see very well at distances (night). U
Captain Sheir wanted to stay with the sinking boat (ship). R
The janitor washed the dirty ashtrays (floors). U
The coach sent the players back to the locker room. BC
Betsy could not read very well without her dictionary (glasses). U
He was knocked off his surfboard by the first bully (wave). U
The company president decided to cancel the board meeting. BC
I ordered a ham and cheese sandwich. BC
Bob proposed but she turned him in (down). U
The sandwich wasn't very good without a slice of cheese. BC
The movie ended so sadly that Julie started to sob (cry). R
I returned the overdue book to the bag (library). U
Her new shoes were the wrong color (size). U
There was a dance after the football game. BC
The winter was very harsh this year. BC
Dick wrote a chapter in the novel (book). R
She tied up her hair in a yellow bow (ribbon). R
Sharon dried the dishes with a kitchen rag (towel). R
My car needs a new coat of paint. BC
While the national anthem plays everyone is expected to behave (stand). U
They placed an ad in the daily paper. BC
He bought the chocolates at the candy shop (store). R
I want mustard, ketchup and relish on my hot dog. BC
I planted string beans in my vegetable garden. BC
After the accident they went for aid (help). R
When you go to bed turn off the lights. BC
Her job was easy most of the time. BC
The winning candidate was preparing his acceptance speech. BC
After dinner they washed the dog (dishes). U
Jill decided to put vanilla icing on the chocolate cookie (cake). R
The maid loaded the laundry into the washing machine. BC
The hungry bear dipped his paw into the sweet honey. BC
Jack's new razor gave him a close clean shave. BC
His kite got tangled in the oak branches (tree). R
The store detective accused him of theft (shoplifting). R
The prisoner was sent back to his duties (cell). U
The housewife asked the plumber to search for her wedding ring. BC
After being robbed the victim called the cops (police). R
It was important to be on top (time). U
Jack ordered a hamburger and french fries. BC
Because he had a toothache he called his boss (dentist). U
They went to the theatre to see a new three act play. BC
Pam didn't have any clothes to donate (wear). U
The careless smoker caused a forest fire. BC
He put on his brakes when the stoplight turned red. BC
He likes lemon and sugar in his coffee (tea). R
She made a salami sandwich on wheat rolls (bread). R
They drove to a private airport to catch the thieves (plane). U

The kids fed the ducks some stale crumbs (bread). R
Don't touch the wet dog (paint). U
The governor vetoed the new bill. BC
The old house will be torn down. BC
George put the record on the record player. BC
Jay was so drunk that he passed out. BC
The organist accompanied the church choir. BC
The child was born with a rare gift (disease). U
Yesterday they canoed down the rapids (river). R
Smoking may be hazardous to your neighbors (health). U
They ate their dinner at the kitchen table. BC
They drank champagne to celebate their twelfth wedding anniversary. BC
They saw the lightning and heard the screams (thunder). U
It felt much colder when the sun was behind a tree (cloud). U
The fasting man didn't eat all day and was very hungry. BC
The magician took out his hat and made a rabbit appear. BC
The squirrel stored some nuts in the hole (tree). U
They could not afford to give their daughter piano lessons. BC
Burt used a match to light the dying flame (fire). R
Each April we must pay our income tax. BC
All the planets circle around the sun. BC
Seeing a black cat is considered bad luck. BC
The car pulled up and took the last parking meter (space). U
Joan warmed the baby's bottle of milk. BC
Pam weighed herself on the bathroom scale. BC
The society's annual dues were fifty bucks (dollars). R
Every spring they hold the annual easter egg hunt. BC
I generally smoke menthol cigarettes. BC
There are twelve inches in a foot. BC

APPENDIX 2

Word pairs. The letter(s) preceding each pair designates the experimental condition to which the word pair belongs: with HR indicating strong semantic or associative relationship, R indicating moderate semantic relationship, and U indicating no semantic or associative relationship. Note that the second word of each pair was the final word of one of the sentences (see Appendix 1) and, in the case of MR pairs, the first word was the expected, high cloze probability (but not shown) ending of a sentence and the second word was related. This relation between the sentences and word pairs constrained the stimuli used.

HR mow–lawn
HR omen–sign
HR pacemaker–heart
HR ice cream–sundae
MR shoes–boots
HR radiator–water
HR wallow–mud
HR elbows–knees
HR marching–band
U foot–watch
MR eat–chew
U color–consistency
HR slumber–sleep
MR cages–captivity
HR flagpoles–flags
MR fog–mist
HR pointed–sharp
U mother–chair
HR pint–quart
MR soup–broth
U time–excuse

HR fork–knife
MR basket–hamper
HR under–over
HR ponder–think
U wrong–asleep
HR workplace–office
MR soon–shortly
HR azure–blue
U swim–sea
HR signup–register
U lost–hurt
HR bad–good
HR multicolored–rainbow
HR mob–crowd
MR baby–infant
U mind–clothes
HR auto–car
MR energy–power
U birth–noon
U list–wall
HR classroom–school
HR month–year
U soil–sink
U soon–hungry
HR sacks–bags
HR cheddar–cheese
U play–shower
MR rain–lightning
HR mink–fur
U escape–picnic
HR viewed–seen
HR chalk–board
HR short–tall
HR mature–age
U tip–clientele
HR gun–holster
MR party–bash
MR damage–harm
MR university–college
U could–dared
HR bake–oven
U time–band
MR plate–platter
MR coffee–tea
U wife–staff
U ground–pipe
HR drip–leak
MR letter–note
U room–counselor
HR laundry–cleaners
HR cloakroom–closet
U cover–help
U heavy–rusty
HR sauna–pool
MR exams–tests
HR sad–happy
MR cars–autos
U late–drunk
MR word–syllable
HR buddies–friends
HR wardrobe–clothes
MR made–designed
HR food–meal
HR retinas–eyes
HR nest–eggs
MR farm–ranch
MR name–address
U pressure–sugar
HR numerals–numbers
HR bank–train
HR salt–pepper
U dictionary–index
MR easy–simple
U office–convenience
U beach–roof
U rest–help
HR atlas–map
MR money–cash
U gun–father
HR bread–loaf
MR plumber–handyman
HR chablis–wine
MR sale–auction
HR melody–tune
U hook–table
HR Sacramento–California
U number–repairman
HR biceps–muscles
MR school–academy
HR uttered–said
U floor–ground
HR enemies–friends
HR animals–zoo
U bad–yellow
HR splatter–splash
MR bank–teller
HR tuxedo–suit
HR maintain–service
U speak–resign
U sink–bedroom
MR time–schedule
HR relay–race
MR party–celebration
HR picket–fence
U name–mistake
HR sprint–race
HR poster–sign
U deal–leave
HR damp–wet
MR fire–blaze
HR shopping–out
MR over–finished
MR rent–bills
MR dry–air
HR relay–race
U wallet–vest
U out–privately
HR cowboys–indians
MR seat–chair
U lie–soul
HR concentration–attention
U broke–poor
HR chamber–room
MR bill–fee
MR safe–vault
U rope–happily
HR desk–drawer
U doors–keys
MR leg–arm
U drugs–movies
MR light–lamp
U leash–diet
MR broom–mop
HR lock–key
U stamp–thought
HR sight–sound
U faulty–turn
U sign–signals
HR desk–chair
HR thermometer–temperature
MR test–quiz
HR England–London
U door–paper
HR bulletin–board
U true–told
MR window–glass
HR nectar–honey
U blond–dry
HR rough–smooth
HR barrier–wall
HR quarterback–football
U tired–good
HR bunk–bed
U lungs–stairs
U court–lunch

MR weeds–roots
HR nine–ten
MR station–depot
MR thread–string
MR drink–slip
HR kilometer–mile
MR bee–wasp
MR door–entrance
U water–minutes
HR liquefied–melted
MR gas–fuel
HR clock–time
HR gate–fence
MR ticket–citation
U closet–back
HR traveller's–check
MR accident–crash
U smell–loyalty
MR horses–stallions
HR tablet–pill
U hair–toes
HR milk–cream
MR steak–meat
HR light–dark
U mother–conversion
MR church–congregation
HR playground–park
HR goul–ghost
U dream–hangover
MR minute–hour
MR cast–splint
HR lettuce–salad
HR bankbook–check
U bugs–skunks
HR apartment–house
U guilty–crazy
MR city–town
U carpet–red
MR road–path
HR seconds–minutes
U hot–cluttered
U ink–care
HR enlarge–grow
MR circle–ring
HR footstool–ladder
MR street–road
HR pair–set
U hear–suspect
HR rooster–hen
HR roller–coaster
HR strangle–neck
U sense–money
U bed–clipboard
HR craziness–insanity
HR diploma–degree
U raise–car
HR level–grade
HR ceiling–floor
HR buttered–popcorn
MR small–little
U identification–ID
HR embrace–hug
HR shingle–roof
U bridge–falls
HR veto–bill
HR up–down
HR teammate–player
HR in–out
HR chorus–choir
U disease–gift
MR river–rapids
HR gathering–meeting
HR BLT–sandwich
U down–in
HR toast–bread
MR cry–sob
U library–bag
U size–color
HR scrabble–game
HR month–year
MR book–novel
MR ribbon–bow
MR towel–rag
HR brush–paint
U stand–behave
HR pencil–paper
MR store–shop
HR cat–dog
HR vegetable–garden
MR help–aid
HR clock–time
HR lecture–speech
U dishes–dog
MR cake–cookie
HR mechanic–machine
HR syrup–honey
HR razor–shave
MR tree–branches
MR shoplifting–theft
U cell–duties
HR jewelry–ring
MR police–cops
U time–top
HR hamburger–fries
U dentist–boss
HR theatre–play
U wear–donate
MR aisles–rows
U home–quietly
HR flame–fire
HR stoplight–red
MR tea–coffee
MR bread–rolls
U plane–thieves
MR bread–crumbs
MR rain–showers
U night–distances
MR ship–boat
U floors–ashtrays
HR space–room
U glasses–dictionary
U wave–bully
U paint–dog
U health–neighbors
HR chair–table
HR commemoration–anniversary
U thunder–screams
U cloud–tree
HR starving–hungry
HR see–appear
U tree–hole
HR homework–lessons
HR income–tax
MR fire–flame
HR moon–sun
HR superstition–lock
U space–meter
U list–wall
HR dairy–milk
HR weigh–scale
MR dollars–bucks
HR search–hunt
HR menthol–cigarettes
HR inch–foot