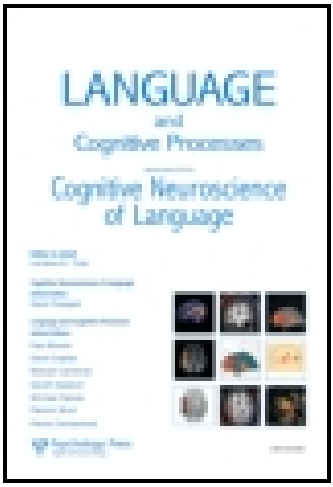

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A comparison of lexical and sentence-level context effects in event-related potentials

Cyma Van Petten [a]

[a] Department of Psychology , University of Arizona , Tucson, Arizona, USA

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A Comparison of Lexical and Sentence-level Context Effects in Event-related Potentials

Cyma Van Petten

Department of Psychology, University of Arizona, Tucson, Arizona, USA

Event-related brain potentials elicited by lexically associated and unassociated word pairs embedded in normal or semantically anomalous sentences were recorded in order to compare the influences of lexical and sentential context. The design of the experiment was such that second words of associated pairs in anomalous sentences could be subject to lexical context alone, while the second words of unassociated pairs in normal sentences could draw on both types of context, while unassociated words in anomalous sentences were included as a control condition wherein no context effects were expected. N400 amplitude was reduced by both lexical and sentential contexts, and the onset latencies of the two effects were similar. The sentential context effect proved to be longer in duration, and exhibited greater variability across subjects. The amplitude of the purely sentential context effect was predictive of subsequent recognition accuracy for other words occurring in the same sentence. The amplitude of the lexical context effect was unrelated to subsequent recognition performance.

INTRODUCTION

Written language can be described at a number of levels of increasing size and complexity, including the letter, bigram, word, sentence and discourse. One of the earliest and most compelling demonstrations that a

Requests for reprints should be addressed to Cyma Van Petten, Department of Psychology, University of Arizona, Tucson, AZ 85721, USA. E-mail: vanpett@convxl.ccit.arizona.edu.

This study formed part of a dissertation submitted in partial requirement for the Doctorate in Neurosciences at the University of California, San Diego. I am grateful to all the members of my dissertation committee: Marta Kutas for continuous support and guidance, Steven Hillyard in whose laboratory the data were recorded, and Elizabeth Bates, Jeffrey Elman and Helen Neville for feedback. Financial support was provided by grants from the National Institutes of Health to Marta Kutas (NICHD HD22614, NIA AG08313) and to the author (NINDS NS30825).

higher level might be more than the sum of its lower-level components in performance, as well as in theory, was the demonstration of a word superiority effect for letter detection (Cattell, 1886; reviewed thoroughly by Henderson, 1982). The search for a similar relationship between sentences and words has been the focus of much psycholinguistic work in the last two decades. The presence, and the locus, of such an effect has been one of the focal points of disagreement in a more general controversy as to whether or not the final product of comprehension should be viewed as the outcome of a number of discrete modular processing units. In the present paper, we contrast sentence-level context effects on single words to lexical, word-to-word, context effects in an attempt to understand the mechanisms by which a word's semantic environment can alter the way it is processed.

The results of a number of tasks including pronunciations (naming latency), distinguishing words from nonwords (lexical decision), verbal report of briefly presented or visually degraded words, colour naming interference (the Stroop task) and monitoring for the occurrence of a target word, have converged to the conclusion that processing of a single word is facilitated by the prior occurrence of a related word (Becker & Killion, 1977; Massaro, Jones, Lipscomb, & Scholz, 1978; Meyer & Schvaneveldt, 1971; Rouse & Verinis, 1962; Warren, 1974; 1977). A priming effect between words that are semantically similar without being associatively related (e.g. "prince–boy") appears to be less robust; it has been observed to be either very small or dependent on the use of a lexical decision task (Fischler, 1977; Huttenlocher & Kubicek, 1983; Lupker, 1984; Seidenberg, Waters, Sanders, & Langer, 1984; Warren, 1977).

The pattern of results across the word–pair experiments can be explained by assuming that lexical context effects (e.g. "priming") take place within a lexicon and are due to the spread of activation between closely linked lexical entries. Sentences, by definition, involve novel combinations of words that cannot be pre-stored. Thus if sentence-level context effects exist, one can conclude either that (1) there are distinct priming mechanisms acting inside and outside a static lexicon, one accounting for lexical priming and others for sentential priming, or (2) that the two varieties of priming act via a similar mechanism that cannot lie within a lexicon immune to outside influences. Many theorists have favoured the first conclusion, that there are fundamentally different varieties of semantic context effects, one arising from closely linked lexical entries, and another from subsequent integrative processes which tie the individual words of a sentence into a conceptual whole (Fodor, 1983; Forster, 1981; Seidenberg, Tanenhaus, Lieman, & Bienkowski, 1982; Swinney, 1991). A large number of experiments have been devoted to the question of whether an incomplete sentence can facilitate the processing of a congruent final

word as measured by accuracy or reaction time. Not all experiments have demonstrated a positive effect of sentence context, but there are a sufficient number to conclude that sentential context effects do exist under some circumstances (Fischler & Bloom, 1985; Kleiman, 1980; Ratcliffe, 1987; Sanocki et al., 1985; Sanocki & Oden, 1984; Schuberth & Eimas, 1977; Schuberth, Spoehr, & Lane, 1981; Schwanenflugel & LaCount, 1988; Stanovich, 1981; Stanovich & West, 1979; 1981; 1983; West & Stanovich, 1978). However, a sufficient number of negative results have accrued to convince some investigators also that sentence context effects are unlikely to occur in normal reading (Henderson, 1982, pp. 351–353; Mitchell & Green, 1978), and that they are restricted to laboratory situations which include: (1) highly predictable final words (Fischler & Bloom, 1979c; (2) visually degraded words (Stanovich & West, 1979); (3) final words that occur at long delays after the sentence fragment; (4) poor readers (Henderson, 1982; Perfetti, Goldman, & Hogaboam, 1979; West & Stanovich, 1978); or (5) cases where sentence priming reduces to word pair priming because some word in the sentence fragment is associated with the final word (Duffy, Henderson, & Morris, 1989). Below, we note some of the methodological stumbling blocks that have contributed to the divergence of opinion.

Assuming that lexical and sentential context effects *can* be obtained under similar conditions, it can still be argued that they arise from qualitatively distinct mechanisms. Many models of the language-processing system are hierarchical, and specify that associative lexical priming and "message level" context effects arise in serially arranged sub-processors. Theories which include an autonomous stage of word recognition may thus grant that both lexical and sentence context effects are possible, but that lexical priming will mandatorily precede any influence of semantic concepts formed by combining words (Fodor, 1983; Forster, 1981; Garrett, 1978; Kintsch, 1988; Seidenberg et al., 1982; Swinney, 1991). It has been difficult to establish the qualitative similarity or difference between lexical and sentential context effects with traditional psycholinguistic measures: a 30 msec reaction time advantage looks like any other 30 msec reaction time advantage whatever the underlying mechanism(s).

The present experiment was designed to evaluate the qualitative similarity between lexical and sentential context effects, and to track the time-course of the two effects by using event-related brain potentials (ERPs) as the dependent measure. Previous work has suggested that the N400 component of the ERP elicited by words is sensitive to both lexical and sentence-level semantic context (for reviews, see Kutas & Van Petten, 1988; in press). This stands in contrast to other components of the ERP, which have been more directly tied to a subject's division of attention between different spatial locations, whether a stimulus is a target or non-

target in a target detection task, or whether or not a stimulus will be remembered in a subsequent recall or recognition task (for reviews, see Hillyard & Kutas, 1983; Hillyard & Picton, 1987; Johnson, 1988; Kutas, 1988; Mangun & Hillyard, 1990; Neville, Kutas, Chesney, & Schmidt, 1986; Paller, 1990).

The amplitude of the N400 is smaller if the eliciting word is related rather than unrelated to a prior word (Bentin, McCarthy, & Wood, 1985; Holcomb, 1988; Holcomb & Neville, 1990; Kutas & Hillyard, 1989; Harbin, Marsh, & Harvey, 1984; Rugg, 1985). In sentences, semantically anomalous final or intermediate words elicit larger N400s than do congruent words (Kutas & Hillyard, 1980a; 1980b; 1980c; 1982; 1983). Moreover, the amplitude of the N400 elicited by *congruous* sentence endings shows a strong inverse correlation with the cloze probability of the ending (Kutas & Hillyard, 1984; Kutas, Lindamood, & Hillyard, 1984). Finally, the amplitude of the N400 to congruent intermediate open-class words shows a linear decline across the course of a sentence (Kutas, Van Petten, & Besson, 1988; Van Petten & Kutas, 1990; 1991a). We have attributed this word position effect to the incremental build-up of semantic constraints across the course of a sentence as it does not occur in random word strings or in syntactically structured but semantically anomalous sentences. However, the sentences used in these prior experiments were not constructed to rule out the possibility that purely lexical relations contributed to the nominal sentence-level effects.

To date, there have been few attempts to contrast directly lexical and sentential context effects in the ERP. Fischler and colleagues have reported both lexical and propositional context effects in separate experiments (Fischler et al., 1983; Fischler, Boaz, Childers, & Perry, 1985). Kutas (1985; 1993) has contrasted single-word and sentence contexts and obtained similar N400 effects in the two conditions, although larger and earlier in latency with sentence contexts. Given the existing data, we expect both lexical and sentential context effects to be visible in the ERP, but comparisons of waveshape and scalp distribution in a single experiment with the same subjects will provide additional evidence as to the similarity or difference of the underlying neural mechanisms.

METHODOLOGICAL CONSIDERATIONS FOR ESTABLISHING THE SIMILARITY OR DIFFERENCE OF LEXICAL AND SENTENTIAL CONTEXT EFFECTS

The present study focuses on the ERPs elicited by critical pairs of associated and unassociated words which were embedded in congruent and semantically anomalous sentences, as shown in Table 1. Across the four

TABLE 1
Examples of the Four Sentence Types

Congruent Associated
1. When the *moon* is full it is hard to see many *stars* or the Milky Way.
2. There were advantages to living in a *city* but Martha moved to a small *town* for the peace and quiet.
3. After studying the map she realized they should have turned *left* instead of *right* at the light.
4. She was glad she had brought a *book* since there was nothing to *read* in the waiting room.

Congruent Unassociated
1. When the *insurance* investigators found out that he'd been drinking they *refused* to pay the claim.
2. The biologist went to the desert every *week* to collect a particular *species* of lizard that he hoped to study.
3. The union officials were worried about the long term health *hazards* of breathing *chemical* fumes every day.
4. She picked up a wallet on the *street* and was honest enough to *try* to locate the owner.

Anomalous Associated
1. When the *moon* is rusted it is available to buy many *stars* or the Santa Ana.
2. There was jewelry to drumming in a *city* but Martha turned to a grey *town* for the lizard and scones.
3. After fixing the movie she found they should have killed *left* instead of *right* at the pot.
4. She was glad she had waved a *book* since there was everyone to *read* in the security child.

Anomalous Unassociated
1. When the *insurance* supplies explained that he'd been complaining they *refused* to speak the keys.
2. The shirt went to the gun every *week* to keep a good *species* of fumes that it hired to see.
3. The star hair was worried about the bared hard drinking *hazards* of signing *chemical* boxes every town.
4. She scrambled up an official black on the *street* and was deep enough to *try* to ring the glue.

Note: The critical pairs of words have been italicised.

sentence types, the second word of a pair could potentially benefit from lexical context alone (Anomalous Associated condition), sentence context alone (Congruent Unassociated), both (Congruent Associated) or neither (Anomalous Unassociated). Responses to sentence words aside from the critical pairs were also recorded.

Choice of a Neutral Baseline

Several studies have contrasted reaction times (RTs) to words when they are preceded by congruous or incongruous sentence contexts, or a "neutral" context, the form of which varies across laboratories from a row

of xxx's, to a random word string, to "the next word is". Fast RTs relative to "neutral" are referred to as facilitation, whereas prolonged RTs are referred to as inhibition. Inhibition for semantically incongruent sentence completions is a fairly common finding, and is usually interpreted to mean that a comprehension failure induced by the incongruous word slowed the behavioural response, independent of the word-level processes of interest (Bradley & Forster, 1987; Forster, 1981; Masson, 1986). On this view, inhibition reflects "post-lexical" factors which are an unavoidable consequence of the behavioural task, rather than a true context effect as seen with lexical priming.

In the present experiment, responses to words embedded in meaningful sentences will be compared to words in sentence-like, but meaningless strings on a word-by-word basis. The influence of a congruous sentence context can thus be examined in a graded fashion, as each additional word can benefit from a longer and longer fragment of the entire sentence. The semantically anomalous strings will serve as a baseline in which words must also be read and processed, but in the absence of a meaningful context. If an anomalous context is actively detrimental, rather than just irrelevant, this too will be apparent as a difference between responses to words at the beginning versus the middle of these anomalous sentences. However, previous results (Van Petten & Kutas, 1991a) suggest that responses to the semantically anomalous words will not vary as a function of word position, and we will not have to invoke different mechanisms to explain facilitatory and inhibitory context effects. Syntactically well-structured strings were chosen as the "no sentence context" condition, since the previous results also suggested that random word lists are less effective for engaging the reader's attention, and make a poor baseline for comparison to normal sentences.

Task

The priming literature is rife with arguments as to the exact nature of the demands imposed by various tasks which exhibit priming effects, and which provides the purest estimate of lexical access (Balota, 1990; Neumann, 1990). In both the sentential and lexical context literatures, the impact of some manipulations such as the proportion of congruous and incongruous items has depended on whether the task was lexical decision or naming latency (Fischler & Bloom, 1985; Sanocki & Oden, 1984; Seidenberg et al., 1984; Stanovich & West, 1983). I would argue that the best experimental task imposes as few artificial constraints on the subject as possible. Reading for comprehension or meaning is a task that the typical experimental subject has practised for many years, and probably continues to practise when he or she enters a lab. An experimenter-

assigned task should add as little as possible to this basic task. The single caveat is that it is useful to place some demand that will serve as both a goad and a measure of the subject's alertness in reading experimental materials that are often less than gripping. Two tasks were assigned to the subjects in the present experiment: to read, and to decide whether or not a subsequently presented word appeared in the sentence. The second task provides some encouragement to do the first. Since subjects do not know what word they will be questioned about, they are encouraged to pay attention to all of them. Because no decisions are required during the sentence, decision criteria and biases will not be confounding factors. The dependent measure of context effect will thus be an observational one provided by the ERPs emitted as subjects read, rather than an additional requirement imposed as they read.

Distinguishing Sentence and Lexical Contexts

Being able to distinguish sentence-level from single-word context effects is a matter for careful stimulus construction. Since there is no full listing of word pairs that can yield lexical priming, experiments that putatively demonstrate sentence-level effects can always be criticised on the grounds that they included associated words (for instances of such criticisms, see Duffy et al., 1989; Forster, 1981; Ratcliff, 1987; Tanenhaus & Lucas, 1987). Previous experiments have demonstrated a word-position effect on N400 amplitude which we take to be an index of sentence-level context (Kutas et al., 1988; Van Petten & Kutas, 1990; 1991a). However, the stimuli for these experiments were not constructed with an eye to ruling out lexical priming effects. In the present experiment, word-position effects will be examined across congruent and anomalous sentences which do not seem to contain associated words. The design also includes a control for inadvertent associations, in that the same pairs of nominally unassociated words occur in both congruent and anomalous sentences.

Time-course of the Two Varieties of Context Effect

Hierarchical, "bottom-up" models of the language-processing system assign lexical and sentential context effects not only to *different* sub-processors, but to *sequentially* arranged sub-processors. The claim has been made that the lower-level processor which produces lexcal priming is immune to higher-level sentence context, so that lexical context can impact an earlier stage of word processing than sentential. The use of an ERP measure provides a means of examining the temporal parameters of context effects well before a subject is capable of producing an overt motor response such as a button press, and the latencies of context effects receive careful attention in the statistical analyses.

METHODS

Subjects

Twenty-eight native English speakers (15 females, 13 males) with normal or corrected-to-normal vision participated as paid volunteers. Their mean age was 23 years (range 18–38 years). Twenty-three were right-handed by self-report; four of these had a left-handed family member. Five subjects were left-handed. The data from one additional subject were not analysed due to excessive eye movement and skin potential artifact during the EEG recording.

Materials

The stimuli were comprised of four classes of sentences: (1) semantically congruent sentences which included a pair of strongly associated words (e.g. salt–pepper); (2) semantically congruent sentences which lacked any strongly associated pairs; (3) syntactically legal but semantically anomalous sentences which included the same associated pairs as the congruent sentences; and (4) syntactically legal but semantically anomalous sentences without such pairs. The mean length of each sentence type was 14.2 words (range 8–22 words). Examples of each sentence type are shown in Table 1, and the congruous sentences appear in the Appendix.

The stimulus set was constructed by initially writing 120 congruent sentences which incorporated semantically associated pairs of words. Neither word of a pair occurred as the first or last word of a sentence. Every attempt was made to avoid using other intermediate words which were associated with each other (or with one of the critical words) outside of the sentence context.[1] For each sentence in this set, a second congruent sentence was written with the following criteria: (1) that it should have the same number of words as the first congruent sentence; (2) that it should contain open-class words in the same ordinal positions as the associated pair in the original sentence (these open-class words were considered the comparable unassociated pair); and (3) that the words which intervened between the first and second members of the associated and unassociated pair should have the same proportion of open- and closed-class words. The

[1]In some cases, it was difficult to avoid using a final word which appeared to be associated with one of the intermediate words. Similarly, some of the sentences contained proper nouns which consisted of two associatively related words (e.g. United States). However, final words are analysed separately from intermediate words, and proper names were excluded from all analyses.

associated and unassociated pairs did not differ significantly in mean frequency of usage, measured as the sum of all regularly inflected forms (Francis & Kučera, 1982). The overall mean frequency was 178 per million [main effect of associated *vs* unassociated: $F(1,119) = 0.68$, NS; word 1 *vs* word 2: $F(1,119) = 1.15$, NS; interaction: $F(1,119) = 1.29$, NS).

The procedure above yielded 240 congruent sentences, half containing associated word pairs and half containing unassociated control words in the same ordinal positions. An equal number of anomalous sentences were generated from these congruent sentences by replacing all of the open-class words in a sentence except the critical word pairs with words from another sentence. Thus, the same set of content words occurred in congruent and anomalous sentences.

While the ordinal position of the critical pairs within their sentences, and the number of words intervening between the first and second member varies widely across the stimulus set (the mean word positions are 7.0 and 10.8), this factor is equated between the four sentence types. Approximately half of the stimulus pairs (59 of 120) consisted of words which were either immediately adjacent, or had one word intervening (usually a closed-class word). The ERPs elicited by these "near" pairs will be considered separately from the "far" pairs where more than one word intervened between the first and second member of the pair.

Each of the sentences contained an average 3.6 intermediate open-class words in addition to the critical pairs (excluding proper names). In the case of the "congruent unassociated" condition, it should be noted that the critical word pairs were distinguished from these other open-class words only on the formal criteria listed above. Thus, any observed difference between the ERPs elicited by the first and second words of these pairs should be a subset of a more general word-position effect occurring over the course of an entire sentence. Each open-class word in both the congruent and anomalous sentences was coded according to its ordinal position to yield five word-position categories: (1) words 2 and 3; (2) words 4–6; (3) words 7–9; (4) words 10–12; and (5) words 13–21. The larger number of words falling into each category (as compared to the critical pairs) allowed us to further subdivide each of these into high and low word frequency, using 30 per million in the Francis and Kučera (1982) count as the dividing line.

A target word was selected to follow each sentence. For each sentence type, half of the targets were words that had occurred in the sentence ("old" targets) and half were not ("new" targets). Both the "old" and "new" targets were evenly divided between open- and closed-class words. Words selected to be "old" targets were distributed across the full range of sentence positions, and this was equated for each of the "old" target types.

Procedure

Each subject was run in two sessions, lasting about 2½ h each, spaced at least 1 week apart. In each session, a subject saw half of the sentences in each of the four classes (60 of each). The two stimulus lists were arranged such that none of the critical word pairs were repeated within a session. Thus, if a subject saw "salt" and "pepper" embedded in a congruent sentence in one session, he or she would see these words embedded in an anomalous sentence in the next session. Within a session, the four classes of sentences were randomly ordered. The order in which the two stimulus lists were presented was counterbalanced across subjects.

The sentences were presented one word at a time on a monitor under the control of an AT computer. Capitalisation and punctuation were normal. The subjects sat 90 cm from the monitor, and a five-letter word was subtended 1.75° at this distance. The inter-word SOA was 600 msec with a duration of 200 msec per word. The target word assigned to each sentence followed 1.5 sec after the onset of the final word. The subjects were instructed to indicate whether or not the target word had been present in the sentence by pressing one of two buttons held in either hand on each trial. Reaction time and accuracy were recorded. Across sessions, the assignment of the left or right hand to represent "old" or "new" was counterbalanced. The interval between the presentation of a target and the beginning of the next sentence was 5.8 sec. The subjects were given a practice set of 20 sentences before beginning the first set, and allowed rest periods between each set of 20 sentences as desired.

Electrophysiological Recording

The electroencephalogram (EEG) was recorded with tin electrodes mounted in a commercially available elastic cap. Midline central (Cz) and parietal (Pz) recording sites were used, along with lateral pairs of electrodes over the posterior temporal (T5, T6) and occipital (O1, O2) scalp as defined by the 10-20 system (Jasper, 1958). Three additional lateral pairs were used: (1) a frontal pair placed midway between F7–F8 and T3–T4 (approximately over Broca's area and its right hemisphere homologue, Bl and Br); (2) a temporoparietal pair placed 30% of the interaural distance lateral and 12.5% of the inion–nasion distance posterior to Cz (approximately over Wernicke's area and its right hemisphere homologue, Wl and Wr); and (3) a central pair that was 33% lateral to Cz (approximately over Brodmann's area 41, L41 and R41). Each scalp site was referred to an off-line average of the left and right mastoids (see Van Petten & Kutas, 1988). Vertical eye movements and blinks were monitored via an electrode placed below the right eye referred to the left mastoid. Horizontal eye movements were monitored via a right-to-left bipolar montage at the external canthi.

The EEG was amplified by a Grass Model 12 polygraph with half-amplitude cut-offs of 0.01 and 30 Hz, digitised on-line at a sampling rate of 250 Hz, and stored on magnetic tape along with stimulus codes for subsequent averaging. Trials with eye movement, muscle, or amplifier blocking artifacts were rejected prior to averaging.

RESULTS AND DISCUSSION

Before turning to the results from the critical word pairs which formed the four conditions of the experiment, it will be useful to examine some more general differences between the congruent and anomalous sentences in the first section of the Results. The data from the critical word pairs are then presented in four main sections: the amplitudes of the N400s elicited; their topographic distribution across the scalp; the relationship between the N400s elicited during the sentence and the post-sentence recognition task; and, finally, the latencies and durations of the experimental effects.

Word Position and Frequency Effects

The ERPs elicited by open-class words other than the critical pairs are shown in Fig. 1. The sentence-intermediate words elicited a prominent negative wave peaking at about 400 msec post-stimulus onset, the N400. Anomalous intermediate words elicited larger N400s than congruent words, and low-frequency words larger N400s than high-frequency words. At sentence-final positions, congruent words elicited very little N400 activity, whereas anomalous words elicited sizeable N400s. Figure 1 also shows that for intermediate words, the N400 frequency effect is less pronounced for congruent than for anomalous words; at final word positions, only the anomalous words continue to show an N400 frequency effect.

The amplitude of the N400 was quantified as the mean voltage within its peak latency range of 300–500 msec, relative to a 100 msec pre-stimulus baseline. The final words were analysed with a repeated-measures analysis of variance (ANOVA) taking sentence type (2 levels), word frequency (2 levels) and electrode site (12 levels) as factors. The larger N400 for anomalous final words yielded a main effect of sentence type [$F(1,27) = 126.8$, $P < 0.0001$], whereas the frequency effect on anomalous words yielded an interaction between sentence type and frequency [$F(1,27) = 4.56$, $P < 0.05$] in addition to a main effect of frequency [$F(1,27) = 4.79$, $P < 0.05$].

The ERPs to the intermediate open-class words (excluding the critical pairs) were broken down in greater detail to examine the influence of the position of words within their sentences. The ERPs in Fig. 2 show that the

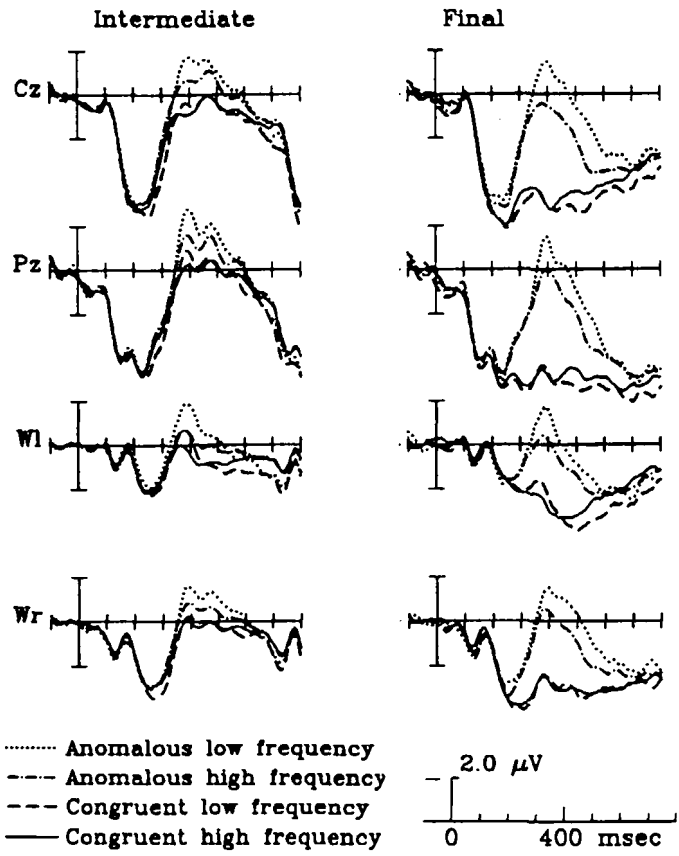

FIG. 1 Grand average ERPs elicited by intermediate and final words of the sentence. The four electrode sites shown are midline central (Cz), midline parietal (Pz), and a left and right posterior temporal pair (Wl and Wr).

amplitude of the N400 declined across the course of congruent but not anomalous sentences. Figure 3 shows N400 amplitude averaged across all of the electrode sites as a function of both word position and frequency in the congruent sentences, whereas Fig. 4 shows the analogous measures for anomalous sentences. These figures suggest that there was indeed a steady decline in N400 amplitude across congruent sentences and an elimination of the word-frequency effect present early in these sentences. In anomalous sentences, there was little change in N400 amplitude during the sentences, and a persistent word-frequency effect.

The mean amplitude measures were analysed via an ANOVA with trend analyses taking word position (5 levels), frequency (2 levels) and scalp site (12 levels) as factors. For words occurring in congruent sentences, there

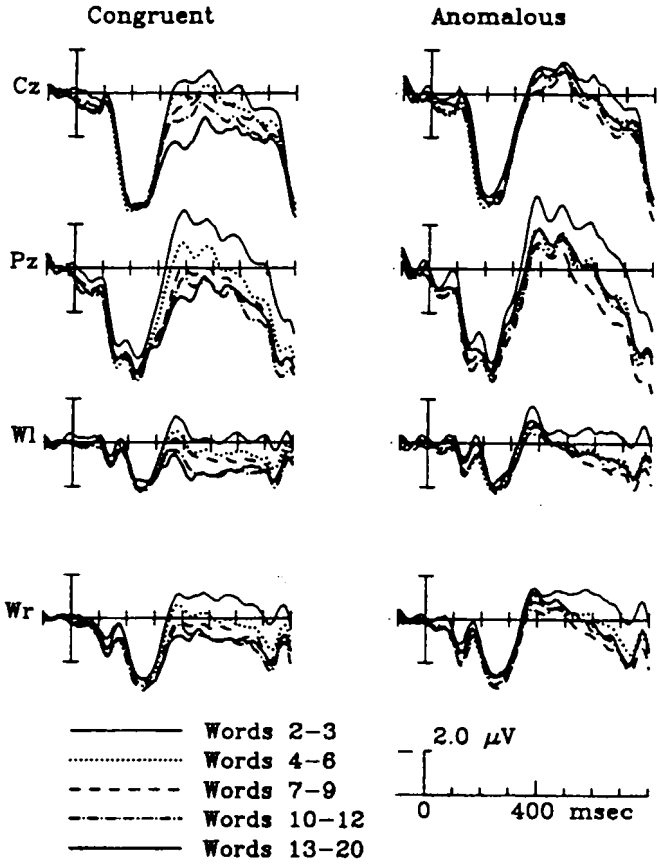

FIG. 2 ERPs elicited by sentence-intermediate words, broken down by position in the sentence. The critical associated or unassociated word pairs are not included in these averages.

was a significant linear effect of word position [$F(1,27) = 47.3$, $P < 0.0001$]; the quadratic, cubic and quartic trends were not significant. The main effect of word frequency was not significant [$F(1,27) = 1.74$], but the interaction between frequency and the linear trend across word position was [$F(1,27) = 10.3$, $P < 0.005$]. In a similar analysis of N400 amplitudes elicited by anomalous words, neither the linear trend [$F(1,27) = 2.06$], nor any of the other orthogonal components of word position were significant. The main effect of frequency was significant [$F(1,27) = 13.3$, $P < 0.002$], but the interaction between frequency and the linear effect of word position was not [$F(1,27) = 0.90$].

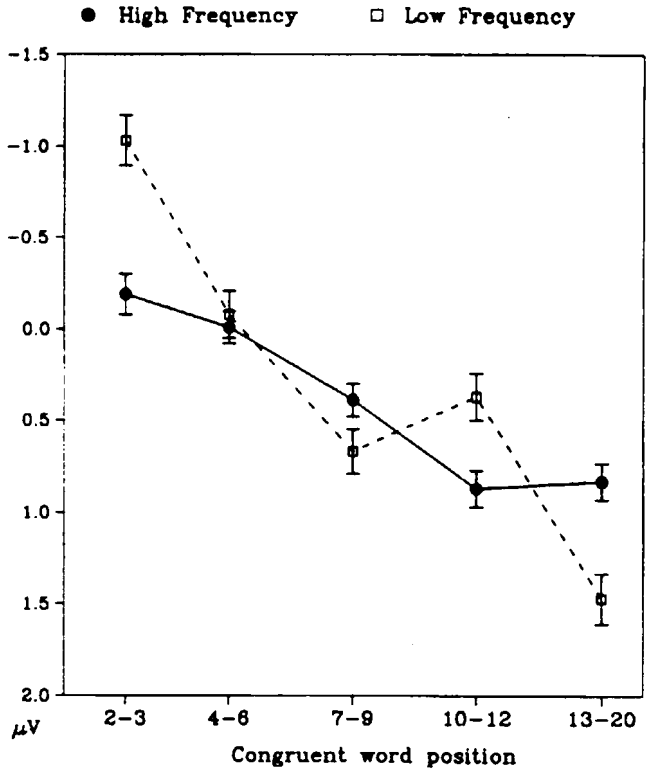

FIG. 3 Mean voltage within the peak latency range of the N400 (300–500 msec post-stimulus onset) for words in the Congruent sentences, relative to a 100 msec pre-stimulus baseline. The amplitude measure is averaged across all of the electrode sites. The critical associated or unassociated word pairs are not included in these measures.

This pattern of results replicates those of previous studies (Van Petten & Kutas, 1990; 1991a) in suggesting that: (1) sentential context is applied incrementally at each word, rather than participating only in "wrap-up" processes occurring at the end of a sentence; (2) as long as a word string is syntactically structured, non-meaningful context has no effect on the processes reflected in the N400, as opposed to an actively detrimental effect; and (3) word frequency plays a role in these processes only when meaningful semantic context is weak, as at the beginning of a congruent sentence, or absent, as in an anomalous sentence. (The frequency × word position interaction is discussed in terms of various models of frequency and context effects in Van Petten and Kutas, 1991b.)

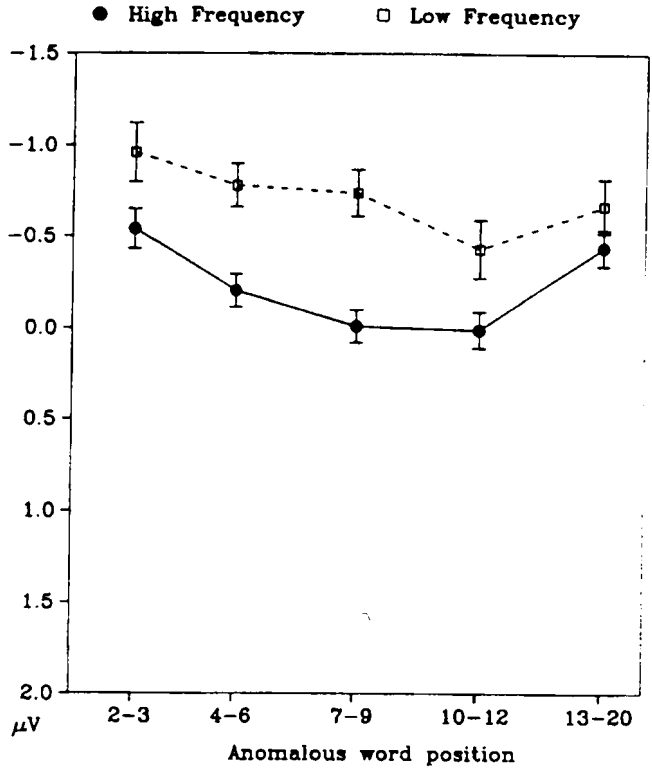

FIG. 4 Mean voltage within the peak latency range of the N400 (300–500 msec post-stimulus onset) for words in the Anomalous sentences, relative to a 100 msec pre-stimulus baseline. The amplitude measure is averaged across all of the electrode sites. The critical associated or unassociated word pairs are not included in these measures.

Critical Word Pairs: Sentential and Lexical Context

In the analyses to follow, the word position effect described above is used as a vehicle to examine sentential and lexical context effects. In the Congruent Unassociated sentences, a decline in N400 amplitude from the first to the second word of the critical pairs will be regarded as the effect of sentence-level context alone. It should be noted that this Word 1/Word 2 contrast is a subset of the more general word-position effect typically observed in congruent sentences. But unlike the more general effect, the critical pairs in the Congruent Unassociated sentences were matched for exact sentence position, word length and word frequency to the associated pairs occurring in the Congruent Associated condition, where a difference from Word 1 to Word 2 may reflect the combined effect of overall sentence

context and the lexical association. These same associated pairs were incorporated in the Anomalous Associated condition (in the same positions as the congruent sentences, sentences of identical overall length), so that a Word 1/Word 2 difference here will be defined as the effect of lexical association in the absence of sentence context. Finally, the unassociated

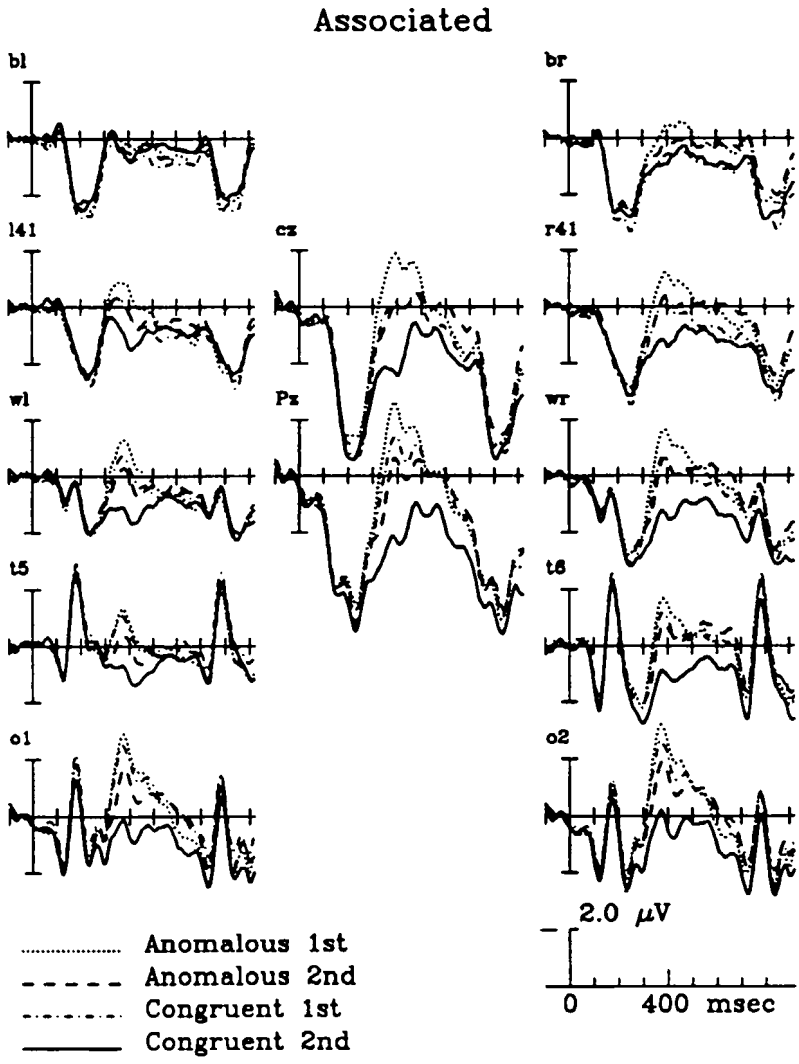

FIG. 5 ERPs elicited by the first and second members of the critical Associated word pairs in Anomalous and Congruent sentences. All of the scalp sites are shown here: the most anterior sites are at the top of the figure, the most posterior at the bottom of the figure. The three columns depict the left side of the head, the midline and the rightt side of the head.

pairs were included in a matched set of anomalous sentences. We expect no Word 1/Word 2 differences in the Anomalous Unassociated condition, but the absence of effects serves as an important verification that any such differences observed in the Congruent Unassociated condition are not due to inadvertent lexical associations, but because the words occurred within a meaningful sentence.

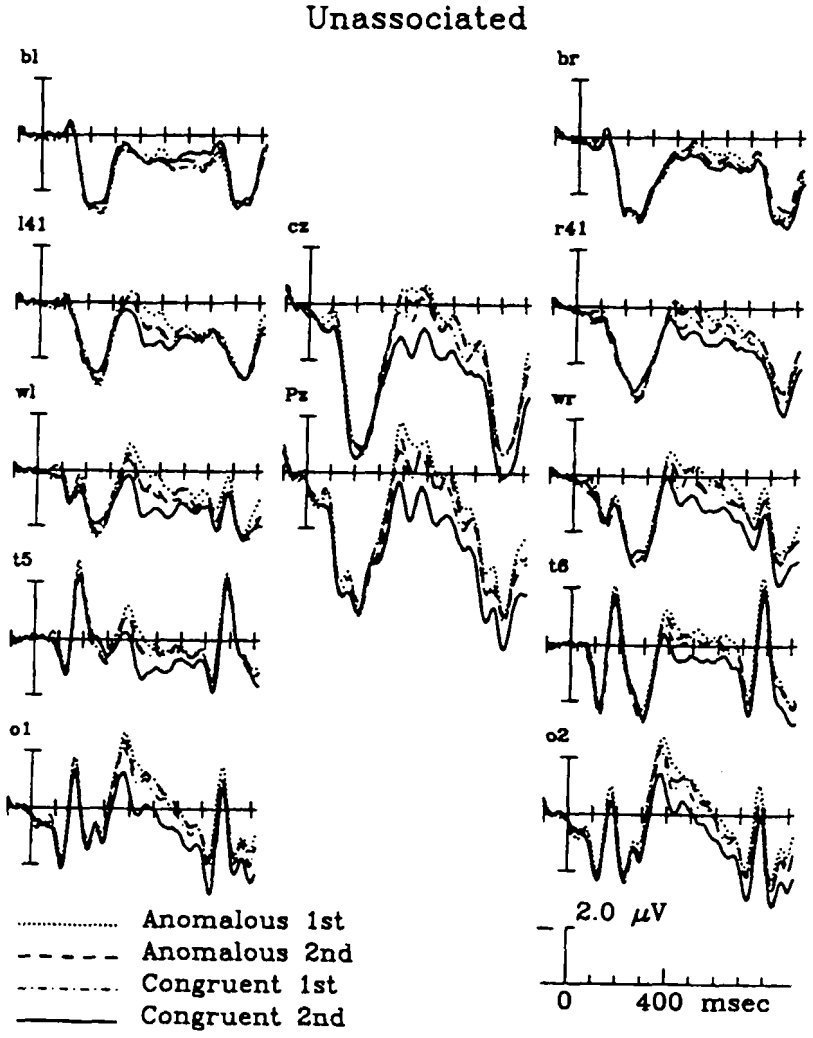

FIG. 6 ERPs elicited by the first and second members of the critical Unassociated word pairs in Anomalous and Congruent sentences. All of the scalp sites are shown here: the most anterior sites are at the top of the figure, the most posterior at the bottom of the figure. The three columns depict the left side of the head, the midline and the right side of the head.

Associated Pairs. The ERPs elicited by the associated pairs of words are shown in Fig. 5. The N400 was quantified as the mean voltage from 300 to 500 msec and subjected to an ANOVA taking sentence type, position in the pair (first *vs* second) and electrode site as factors. The second words of associated pairs elicited smaller N400s than did the first words [$F(1,27) = 52.4$, $P < 0.0001$]. There was also a main effect of sentence type, indicating that the same words elicited smaller N400s when embedded in congruent rather than anomalous sentences [$F(1,27) = 52.0$, $P < 0.0001$]. Separate pairwise comparisons showed that this was true of the first [$F(1,27) = 25.9$, $P < 0.0001$] and second [$F(1,27) = 40.0$, $P < 0.0001$] members of the associated pairs. Finally, there was an interaction between sentence type and position within the pair because the reduction in N400 amplitude from the first to the second word was greater in the congruent sentences [$F(1,27) = 6.47$, $P < 0.02$]. Pairwise comparisons showed that the difference between the first and second members of the pairs was significant in both sentence types [Congruent: $F(1,27) = 45.5$, $P < 0.0001$; Anomalous: $F(1,27) = 32.9$, $P < 0.0001$].

Unassociated Pairs. The ERPs elicited by unassociated pairs are shown in Fig. 6, and were analysed as above. There were significant main effects of position [$F(1,27) = 7.52$, $P < 0.02$] and sentence type [$F(1,27) = 23.0$, $P < 0.0001$]. As for the associated pairs, both the first [$F(1,27) = 12.0$, $P < 0.0002$] and second [$F(1,27) = 15.4$, $P < 0.0005$] words of the unassociated pairs elicited smaller N400s when embedded in congruent as opposed to anomalous sentences. In the overall ANOVA, the interaction between sentence type and pair position was not significant [$F(1,27) = 2.20$]. However, planned comparisons showed that the amplitude reduction from first to second word was significant in the congruous sentences [$F(1,27) = 6.58$, $P < 0.02$] and not in the anomalous ones [$F(1,27) = 2.74$].

Scalp Distribution of the Pair Effects

It is of some interest to determine whether the lexical and sentential ERP context effects have different scalp distributions, since this would indicate different (although possibly overlapping) neural generators. Scalp distribution analyses were conducted by first isolating the two context effects by forming difference waves, consisting of the ERP elicited by the first word of a pair minus the ERP elicited by the second word, as shown in Fig. 7. The difference waves were then normalised to have the same mean amplitude when averaged across all scalp sites,[2] and the normalised values

[2]Some normalisation procedure of this type is necessary because the additive model used by an ANOVA yields spurious interactions between scalp site and experimental effect if the experimental effects are of different overall amplitude (see McCarthy & Wood, 1985). As an

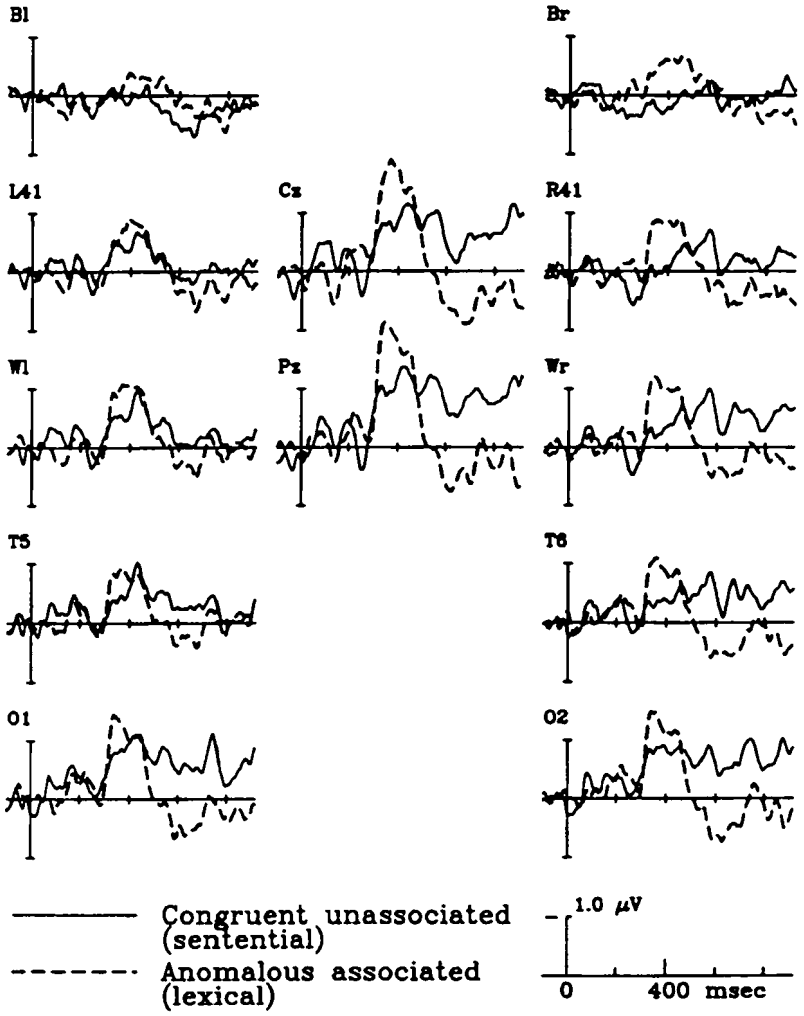

FIG. 7 Difference waves formed by subtracting the ERP elicited by the second word of a critical pair from the ERP elicited by the first word. The solid line is the sentence-level context effect derived from the Congruent Unassociated pairs, the dashed line is the lexical context effect derived from the Anomalous Associated pairs. Both effects include a reduction in N400 amplitude. Note that the lexical effect is larger in the peak latency range of the N400, but the sentential effect is more prolonged.

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illustration, consider the following hypothetical pattern of results: Effect A is 4 μV at Electrode 1 and 2 μV at Electrode 2; Effect B is 2 μV at Electrode 1 and 1 μV at Electrode 2. Both effects have the same scalp distribution of being twice as large at Electrode 1 as Electrode 2, but Effect A is twice as large at both sites. Despite the identical scalp distribution, these data may yield a significant Effect × Electrode interaction in an ANOVA because the difference between effects was 2 μV at Electrode 1 and only 1 μV at Electrode 2.

from the lateral electrode sites were then subjected to an ANOVA with factors of "context type", laterality and a factor reflecting the anterior–posterior scalp dimension (five levels). In this type of analysis, differential scalp distributions show up as interactions between "context type" and one or both of the scalp site factors. The analysis yielded a main effect of the anterior–posterior factor [$F(4,108) = 9.60$, epsilon = 0.41,[3] $P < 0.0005$], reflecting the generally small amplitude of the context effects at the most frontal electrodes. There was no main effect of laterality. The scalp distributions of the two context effects did not differ significantly [context type × anterior–posterior: $F(4,108) = 0.40$; context type × laterality: $F(1,27) = 1.44$].

Summary of the Word-pair Amplitude Effects

The pair effects indicate that both sentential and lexical/associative context effects are reflected in N400 amplitude. The reduction in amplitude from the first to the second member of the word pairs in the Anomalous Associated condition can only be attributed to lexical priming, whereas the pair effect in the Congruent Unassociated condition can only be attributed to sentence-level processes. In the latency range evaluated (300–500 msec post-stimulus onset), the two varieties of context effect had indistinguishable scalp distributions, thus yielding no evidence that they arose from different populations of neurons.

The condition where both varieties of context could be applied to the second words of the critical pairs (Congruent Associated) yielded a larger context effect than either variety of context in isolation (Congruent Unassociated or Anomalous Associated). The purely lexical and purely sentential context effects seen in the other two conditions seemed to be additive in producing the larger joint context effect in the Congruent Associated condition, as seen in Fig. 8. The mean amplitude of the Congruent Associated effect in the 300–500 msec window was $-1.22\ \mu V$ (standard error $0.08\ \mu V$ across subjects and electrodes), while the mean amplitudes of the other two effects summed to $-1.33\ \mu V$ (standard error $0.11\ \mu V$) and these were not significantly different [$F(1,27) = 0.21$]. The same analysis for the 500–700 msec window also yielded no significant difference [$F(1,27) = 1.58$]. Because the stimulus sentences in the various conditions were different, the microvolt-by-microvolt additivity of the lexical and sentential context effects to produce the joint effect is probably not of great interest. The exact amplitudes of a sentential context effect

[3]The Huynh–Feldt correction for violations of sphericity was used in all ANOVAs. We report here the original degrees of freedom and the epsilon correction factor.

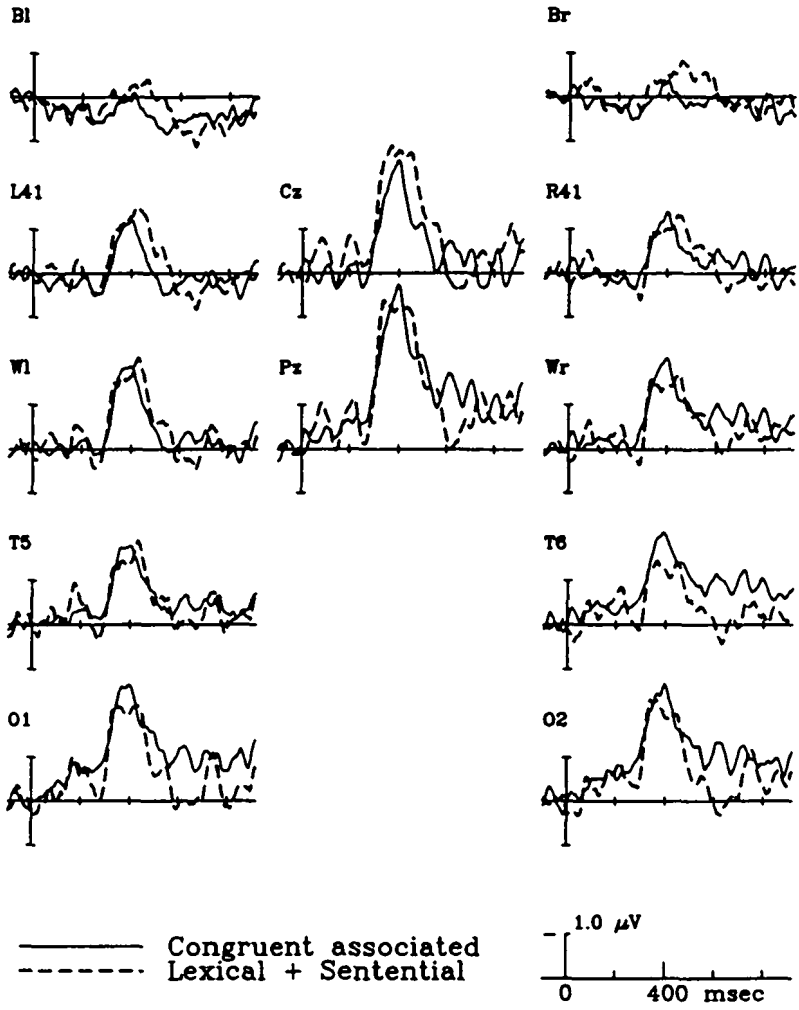

FIG. 8 Can the joint context effect observed in the Congruent Associated condition be attributed to a summation of a purely lexcial effect and a purely sentential effect? The solid line shows the context effect (Word 1 minus Word 2) in the Congruent Associated condition. The dashed line shows the summation of the context effects in the Congruent Unassociated and Anomalous Associated conditions (the individual difference waves for these conditions are shown in Fig. 7).

will depend on the exact level of contextual constraint exercised on particular words by the preceding context, a factor which is difficult to quantify for intermediate words. Of greater interest is that no qualitatively distinct signature of the joint context effect was observed; the general

waveshape, duration and scalp distribution of the joint effect was similar to that of the summed effects of sentential and lexical context.

It is clear that the sentence-level context effect observed in the typical peak latency range of the N400 was weaker than the lexical context effect. It was statistically significant in the planned comparison between the first and second members of the critical pairs, but did not result in a significant interaction when ERPs to the same words in congruent and anomalous sentences were compared. Two factors contributed to the weakness of the effect. First, the pair effect in the Congruent Unassociated sentences should be regarded as a subset of the more general word-position effect shown in Figs 2 and 3. The average sentence positions of the first and second words of the unassociated pairs are roughly equivalent to the position categories of "7–9" and "10–12" in those figures. In the absence of lexical association, the N400 decrement between these word positions is a small though reliable effect. The second factor which contributed to the weakness of the pair-position effect for unassociated words was that it showed considerable between-subject variability, more so than the lexical/associative priming effect. The coefficient of variability for the effect size in the Congruent Unassociated condition (1.94) was nearly double that of the Anomalous Associated condition (0.98).[4] This variance difference may indicate that the application of sentential context demands greater attentional or mnemonic resources than does the application of lexical context. The behavioural task of probe recognition taps mnemonic processes, and was assigned to encourage subjects to read the sentences attentively. Below, we will assess the degree to which sentential context effects were correlated with better performance in the probe recognition task.

Relationships Between the ERP Context Effects and the Recognition Task

Reaction time and accuracy in the probe word recognition task are shown in Table 2. The critical pairs of words were never used as targets, so for these behavioural results the four sentence types were collapsed into simple categories of congruent versus anomalous. Reaction times were analysed by an ANOVA taking into account sentence type, lexical class of the target word (open or closed) and whether or not the target had occurred in the preceding sentence (old or new). The predominant findings

[4] "Effect size" is the N400 amplitude difference between the first and second words of a pair. The coefficient of variability is the standard deviation of this effect divided by the mean. Because it is a ratio, this number is unaffected by the size of an effect and describes intersubject variability.

TABLE 2
Post-sentence Probe Recognition Task[a]

	RT (% errors)		*d'*	*Beta*
	Old Words	*New Words*		
Congruent				
Open	831 ±31 (7)	839 ±36 (8)	3.1 ±0.1	1.3 ±0.2
Closed	871 ±38 (12)	967 ±39 (9)	2.7 ±0.1	1.8 ±0.3
Anomalous				
Open	851 ±41 (13)	837 ±35 (4)	3.0 ±0.1	3.9 ±0.4
Closed	860 ±40 (11)	976 ±48 (13)	2.6 ±0.1	1.3 ±0.2

[a]Reaction times and standard errors in msec.

were: (1) reaction times were faster for open- than closed-class words [$F(1,27) = 63.4$, $P < 0.0001$]; (2) "old" targets were faster than "new" ones [$F(1,27) = 9.69$, $P < 0.005$]; and (3) there was no difference between congruent and anomalous sentences [$F(1,27) = 0.57$], nor any interaction between lexical class and sentence type [$F(1,27) = 0.01$]. Table 2 shows that although half of the targets in each combination of sentence type/lexical class were present in the preceding sentence, and half not, subjects did not distribute their yes/no responses equally among the conditions, but showed differential response biases (betas). For this reason, we will focus on the d' as a measure of accuracy, considering correct responses to "old" targets as hits, and incorrect responses to "new" targets as false alarms. The accuracy analysis showed significantly worse discriminability for closed- than open-class targets [$F(1,27) = 48.8$, $P < 0.0001$], but no difference between the sentence types [$F(1,27) = 1.72$], nor any interaction between sentence type and lexical class [$F(1,27) = 0.02$]. These results largely replicate those of a previous study (Van Petten & Kutas, 1991a).

The probe word recognition task was assigned primarily to help subjects stay alert and involved in the primary task of reading. We might, however, wonder if there are any factors common to good recognition performance subsequent to a sentence, and ERP context effects during a sentence. Rote memorisation would not be the best strategy for obtaining high performance in the recognition task as the sentences averaged 15 words in length. Rather, a reading strategy which focused on phrases or some meaningful unit larger than a single word would lead to more efficient encoding and better recognition performance. The general finding that people are better at recalling semantically or syntactically structured strings than random strings has been attributed to such encoding differences (Miller & Isard, 1963; Wang, 1970). The observation of an overall word-position effect in

congruent but not in anomalous sentences, as well as the subset of the word-position effect appearing as a reduced N400 from the first to second words of the Congruent Unassociated pairs, suggests that these N400 effects are also indicative of a reading strategy that integrates single words into larger conceptual units. So, on the one hand, we might expect the ERP sentential context effects and recognition performance to be correlated because they share a common basis in the active use of sentence-level context while reading. On the other hand, we might imagine that the ERP context effects and recognition performance are not so directly linked, but rather that both are simply larger in subjects with better memories. Carpenter and Just (1989; Just & Carpenter, 1993) have indeed argued that there is a strong correlation between working memory capacity and reading comprehension ability.

On either account, we would expect to find that recognition performance is related to the ERP *sentential* context effects. The primary distinction is that the "generally better memory" account would predict that the size of a subject's sentential context effect would correlate with recognition performance in all of the target conditions, whereas a more direct link between the ERP and recognition data would produce a correlation only for targets following congruent sentences. Note that neither account would predict any correlation between the *lexical* context effect and recognition performance; the words used in the critical pairs never appeared as recognition targets, and there is little reason to think that appreciating the associative relationship in the Anomalous Associated condition would improve one's memory for the other words in the sentence.

Because both recognition performance and ERP indices of contextual utilisation were continuously varying measures, the relationships among them were evaluated with stepwise regression analyses (BMDP 2R; Dixon, 1988). Each of the four d' scores from all subjects (open- and closed-class targets following congruent and anomalous sentences) were used as dependent variables in separate analyses. Three predictor variables were derived from the ERP data: the slope of each subject's overall word position effect in congruent sentences (one metric of the impact of sentential context); the amplitude of his or her pair position effect in the Congruent Unassociated condition (a second metric of sentential context); and the amplitude of the pair-position effect in the Anomalous Associated condition (a metric of lexical context). The minimum F-value to enter a regression equation was set at 3.0. For closed-class targets following anomalous sentences, none of the predictor variables met this threshold. For closed-class targets following congruent sentences, the two ERP measures of sentential context proved to have some predictive power, yielding an R^2 of 0.40 [$F(2,25) = 8.30$, $P < 0.002$]. For the open-class targets following both congruent and anomalous sentences, the ERP indices of sentential context had a small but

significant ability to account for variance in the d' score [congruent: $R^2 = 0.15$, $F(2,25) = 5.66$, $P < 0.01$; anomalous: $R^2 = 0.18$, $F(2,25) = 5.98$, $P < 0.01$]. The lexical priming effect reflected in the Anomalous Associated condition did not meet the minimum criterion to enter any of the regression equations.

As expected, the ERP indices of the use of sentential context were predictive of subsequent recognition performance for words appearing in the sentences, whereas the lexical priming effect was not. The R^2 values were of only moderate size, but this was not surprising given that the ERP predictor variables were global indices of the use of sentential context. A more fine-grained analysis relating the recognition of individual "old"

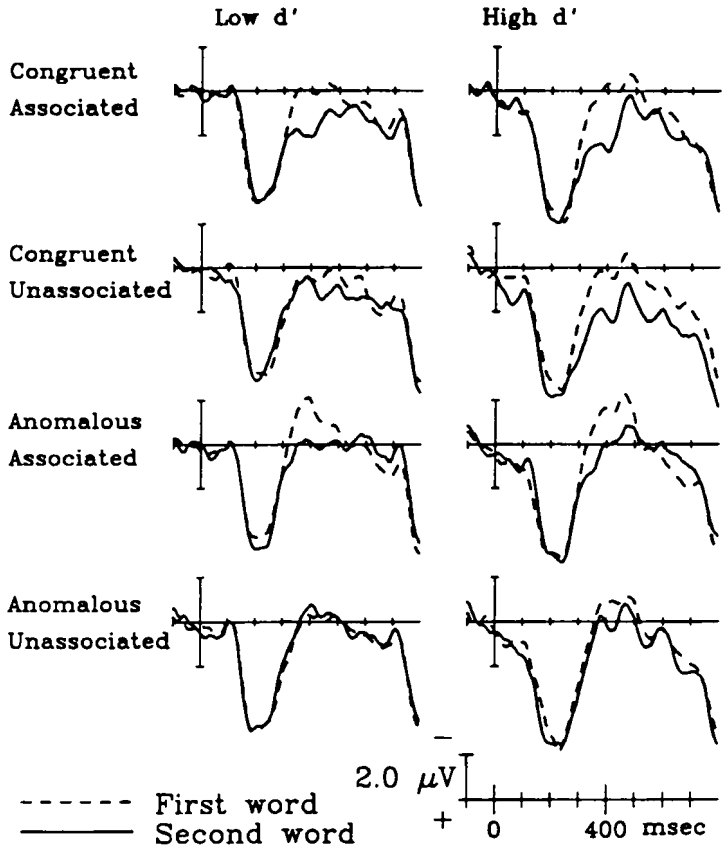

FIG. 9 ERPs elicited by the critical word pairs, as a function of d' in the post-sentence recognition task, for closed-class targets following congruent sentences. The 28 subjects were divided into two groups of 14 showing better and worse performance on these targets. See text for regression analyses of the relationship between the context effects and d'.

target words to the ERPs elicited by those words when they initially occurred in the sentences might have yielded stronger ERP–memory correlations. In the current analysis, the ERP indices of sentential context had the most predictive power for closed-class targets following congruent sentences. Figure 9 illustrates the magnitude of this relationship by showing the ERPs to the critical word pairs when the subjects were divided into two equal size groups based on their recognition performance for these targets. Figure 9 shows that it is primarily the sentence-level context effect (Congruent Unassociated) which differentiates the two groups. Figure 10 shows the difference in the slope of the overall word-position effect when subjects are divided in this manner. It should be noted, however, that Figs 9 and 10 are rough illustrations only; the statistical analyses included each individual subject's performance and ERP measures rather than simply

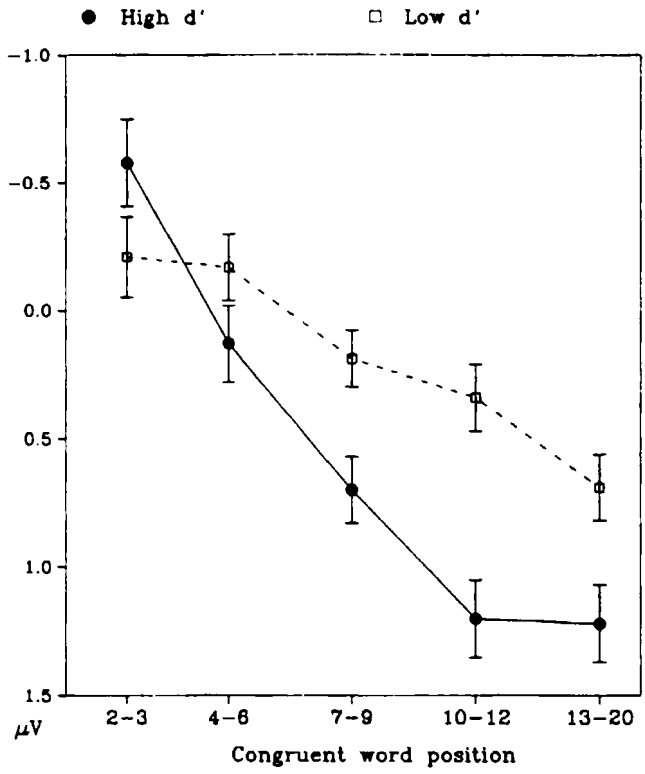

FIG. 10 As in Fig. 3, the mean amplitude of the N400 elicited by words in congruent sentences is plotted against sentence position. The solid line depicts the decline in N400 amplitude for half of the subjects with better performance (high *d'*) in the post-sentence recognition task (closed-class targets following congruent sentences); the dashed line shows the word position effect for the other half of the subjects with worse performance.

dividing the subjects into two groups based on performance as done for the figures.

The results did not clearly discriminate between the "generally better memory" and the more direct accounts of the relationship between brain activity while reading and recognition performance later. The correlations were larger for targets following congruent than anomalous sentences, in accord with the idea that the electrophysiological and behavioural measures shared a common basis in an integrative reading strategy which could only take place in the congruent sentences. The small but significant R^2 for anomalous open-class targets, however, suggests some residual influence of subjects' general mnemonic ability, so that those subjects with better memories were more able to avail themselves of sentence context *and* be more successful in the recognition task.

Temporal Parameters of the Lexical and Sentential Context Effects

The analyses thus far have concerned the amplitudes of lexical and sentence-level context effects, their distributions across the scalp, and their relationship to individual differences. But as noted in the Introduction, one of the strengths of the ERP technique is that we can also examine directly the time-course of the two varieties of context effect.

Onset Latency. The onset latency or "rise time" of a context effect on the processing of a given word can be broken down into two parameters: the time it takes to process a prior context to a level where it *may* be applied to subsequent words, and the time at which it is *actually* applied to the current word. The first parameter can only be estimated by varying the interval between the context and the word to which the subject responds (behaviourally or electrophysiologically). This parameter is beyond the scope of the present experiment, since words were presented at a single rate.[5] We will focus here on the second parameter of onset latency. Reference to Figs 5, 6 and 7 will show that each of the three significant pair effects began at about 250 msec post-stimulus. The onset latencies of the pair effects were measured in the difference waves formed by subtracting the ERPs to the second words of the pairs from those elicited by the first words of the pairs. A "fractional peak latency" algorithm was used to define the first time-point when a difference wave reached 10% of its eventual peak amplitude. Across scalp sites, these latencies were 272 msec

[5]In a subsequent experiment, similar stimuli were presented at a rate of one word every 300 msec (Van Petten et al., in prep.).

in the Congruent Associated condition (sentential and lexical context), 249 msec in the Congruent Unassociated condition (sentential context alone) and 284 msec in the Anomalous Associated condition (lexical context alone), with no significant difference among them [$F(2,54) = 2.47$].

A second, more general measure of the sentential context effect was derived by subtracting the ERPs elicited by all of the open-class words in congruent sentences from those elicited by open-class words in anomalous sentences. For intermediate words, the N400 difference wave reached 10% of its peak amplitude at 270 msec; for final words, 268 msec.

Duration, or Offset Latency. Although both sentential and lexical context effects had a significant impact on the ERPs elicited by the word pairs, Figs 5, 6 and 7 suggest that the pair effects in congruent sentences were more prolonged than the lexical/associative effect seen in the Anomalous Associated condition, particularly over the right hemisphere. This impression was evaluated by measuring the mean voltage of the ERPs in a second latency window, from 500 to 700 msec post-stimulus. For both of the congruent conditions, the second word elicited a significantly more positive ERP than the first in this time window [Associated: $F(1,27) = 4.51$, $P < 0.05$; Unassociated: $F(1,27) = 6.08$, $P < 0.03$]. In the Anomalous Associated condition, the difference between the first and second words was not significant in this later time window [$F(1,27) = 3.03$]. As in the earlier latency window, there was no difference in the Anomalous Unassociated condition [$F(1,27) = 1.34$]. A more direct comparison of the durations of the "pure sentential" and "pure lexical" context effects was performed by comparing the 500–700 msec latency window for the two difference waves (those shown in Fig. 7); the longer duration of the sentential context effect yielded a significant main effect of "context type" [$F(1,27) = 10.5$, $P < 0.005$].

The scalp distributions of the latter portion of the pair effects were analysed as above for the earlier latency window. There was a significant main effect of laterality, indicating that unlike the earlier portion of the pair effect in congruent sentences, the latter portion was larger over right hemisphere sites [$F(1,27) = 12.4$, $P < 0.002$]. As for the earlier latency window, there was also a main effect of the anterior–posterior factor, again reflecting the small amplitudes of the context effects frontally [$F(4,108) = 18.6$, epsilon = 0.38, $P < 0.0001$].

The finding that sentential and lexical context resulted in a common bilaterally symmetric effect in the early latency window, while sentence context also resulted in a later asymmetric effect, might be taken as an indication of two distinct context-sensitive components of the ERP. Additional experiments will be required to document the conditions which yield dissociations between the two latency windows. However, we can ask whether the late asymmetric portion of the sentential context effect is a reduction of an asymmetric negativity present for the anomalous words, or

the addition of a distinct positive component for the congruous words. Analyses of the ERPs elicited by intermediate words in anomalous sentences show that the 300–500 msec latency window is not asymmetric [main effect of laterality: $F(1,27) = 1.39$], whereas the 500–700 msec latency window is [$F(1,27) = 10.9$, $P < 0.005$]. Similarly, words occurring too early in congruent sentences to benefit from much context (word positions two and three) also show a negativity which is symmetric in the early window, but asymmetric in the later window [main effect of laterality, 300–500 msec: $F(1,27) = 0.01$; 500–700 msec: $F(1,27) = 10.4$, $P < 0.005$]. These results suggest that the late, asymmetric effect of sentential context is the reduction of a negativity, just like the earlier symmetric effect. It may be a peculiarity of the current data set that only the second latency window showed an initial right–left asymmetry in the absence of semantic context; most other experiments show that the N400 is larger over the right hemisphere within its peak latency range of 300–500 msec (Gunter, Jackson, & Mulder, 1992; Holcomb & Neville, 1990; Kutas & Hillyard, 1982; Kutas et al., 1988; Van Petten et al., 1991).

Given that the choice of latency window dissociates lexical and sentential context, it will also be helpful to know if there are any other dissociations contingent on latency window. For congruous words, the late epoch shows essentially the same pattern of experimental effects observed in the earlier epoch: a linear trend for word position [$F(1,27) = 21.0$, $P < 0.0005$] and an interaction between the linear trend and word frequency [$F(1,27) = 9.2$, $P < 0.005$]. For anomalous words, the later window was like the earlier one in showing no impact of word position, but the word-frequency effect present in the 300–500 msec window was lacking in the analysis of the 500–700 msec window [$F(1,27) = 0.02$]. This pattern of results indicates that word frequency and lexical context are similar in producing only short-duration effects on the ERP, whereas sentence-level context produces a longer duration effect.

Duration of Context Effects Within a Sentence. Like rise time, the decay time of a context effect can also be subdivided into two parameters. The duration of sentential and lexical context effects during the processing of the "primed" word was described in the preceding section. The second parameter consists of the *potential* duration of a context effect as assessed by the number of subsequent words which may be affected. The overall word-position effect shown in Figs 2 and 3 suggests that the sentential context effect extended for the duration of the sentence; its incremental nature indicates that each word benefited from all of the preceding words, not just the immediately preceding word or two. Of course, these results were obtained from a large set of syntactically diverse sentences; a more fine-grained analysis might demonstrate clausal boundaries for the word-position effect. This possibility can only be evaluated by the use of structurally homogeneous sentences in future research.

In contrast to the cumulative nature of sentential context, lexical context is discrete and can be localised to the preceding associate. The associated pairs embedded in the anomalous sentences were split into two categories defined by the number of intervening words: zero or one versus two or more. The absence of a general word-position effect in the anomalous conditions indicated that these intervening words contributed no relevant context for the second words of the pairs. In the Anomalous Associated condition, a comparison between the "near" and "far" pairs can thus serve to evaluate the potential duration of lexical priming effects in syntactically structured word strings. Measures from the two N400 latency windows (300–500 and 500–700 msec) were subjected to an ANOVA with position in the pair (first *vs* second), distance between the two words (near *vs* far) and scalp site (12 levels) as factors. In this analysis, a decrease in the potency of the lexical priming effect due to intervening words would show up as an interaction between pair position and distance. This interaction was not significant in either latency window [300–500 msec: $F(1,27) = 0.01$; 500–700 msec: $F(1,27) = 1.55$].

The insensitivity of the lexical priming effect to the number of intervening words stands in contrast to the results of random word lists which show a dramatic decline with intervening words (Foss, 1982; Gough, Alford, & Holley-Wilcox, 1981; Neely, 1977; O'Seaghdha, 1989; Warren, 1972). It is in accord with the results of O'Seaghdha (1989) in suggesting that syntactically structured word strings act to prolong lexical priming effects; he found that "the *author* of this *book*" yielded priming, whereas "the *author* the and *book*" did not. However, in the only other experiment to examine lexical priming in anomalous strings that form full sentences like those used here, Simpson and colleagues found a significant lexical priming effect only when the words were close together (Simpson, Peterson, Casteel, & Burgess, 1989). The discrepancy between those results and the present ones may be due to the fact that the "far" pairs here were not as far apart as those of Simpson et al. (an average of 4.8 *vs* 8.3 intervening words). Alternatively, the different results may reflect greater statistical power in the present experiment due to the larger number of sentences per condition (60 *vs* 16).

GENERAL DISCUSSION

Similarities Between Lexical and Sentence Contexts

The most important conclusion to be drawn from the present results is in accord with the picture emerging from recent behavioural studies, that

sentential context effects cannot be attributed to lexical priming (see Foss, 1982; O'Seaghdha, 1989; Sanocki et al., 1985; Simpson et al., 1989). If this were the case, we would not have observed that a difference between the first and second words of unassociated pairs was contingent upon whether they were embedded in congruent or anomalous sentences. However, unlike earlier studies, the present experimental design allowed a direct comparison between the two varieties of context effects. These proved to be similar in one crucial regard: the onset latencies were the same. This rules out the possibility that lexical and sentential context effects arose from serial stages in language processing.

It is important to note the difference between the onset latencies measured in the present experiment, and the manipulations of stimulus onset asynchrony (SOA) often used to infer the speed of different mental operations in reaction time studies. If a context effect can be obtained with a brief interval between two words, it is sometimes suggested that the context was processed and applied within the time-window established by the SOA. The hazards of drawing such a direct relationship between SOA and processing time are clear when the logic is taken to its extreme. Reaction time priming effects from a single associated word have been detected at context-target SOAs as short as 16 msec (Simpson & Burgess, 1985). We would not want to conclude that the meaning of the prime word was accessed within 16 msec and subsequently influenced the processing of the target word, because visual information will not have reached even primary visual cortex at this point in time (semantic processing in the retina or the lateral geniculate is unlikely). With such short inter-stimulus intervals, some processing of the context clearly occurs after the presentation of the target and the observed semantic priming effect is due to coincident processing of the two words rather than preactivation of the second word by the first. We would like to suggest that whenever observed reaction times exceed the duration of the mental process of interest (which is nearly always), the rise time for a semantic context effect cannot be fully described by the minimum SOA required to obtain the effect. Rather, the rise time of a semantic context effect can more fruitfully be thought of as two distinct parameters: the time required to read and compile a context to the point where it *may* be applied to a subsequent word, and the point in the processing of a current word where context *is* applied. SOA manipulations remain the best available technique for estimating the first parameter, since the subject can be given more or less time to process the context. In the present study, sentence words were presented at the relatively slow rate of one every 600 msec. We assume that, at the presentation of each new word, the subjects have processed the prior context as extensively as they ever would, so that the entire sentence fragment up to that point is available to serve as context. The latencies of the context effects 250 msec

post-stimulus then serve as a metric of the second aspect of rise time.[6] The indistinguishable latencies for sentential and lexical context provide no support for the idea that word processing is susceptible to lexical context at a stage when access to sentential context is blocked.

The latency of the N400 has received less attention than its amplitude in previous research, but one line of research has suggested that N400 latency is affected by manipulations which influence the time at which information first enters the language-processing system. The N400 difference between auditory words with and without contextual support can begin somewhat earlier than the analogous visual difference (Holcomb & Neville, 1990; 1991; Kutas, Neville, & Holcomb, 1987). This context effect on auditory words is usually apparent at a latency shorter than the duration of the spoken words, in accord with the finding that many words can be recognised before their completion (Grosjean, 1980; Tyler, 1985). The auditory N400 studies have suggested that short latency context effects may be due to co-articulation phenomena between the previous and eliciting words. In other words, some acoustic information about the N400-eliciting word may be present before its nominal onset, so that the amount of additional acoustic information required to recognise the word is lessened. Manipulations which disrupt co-articulatory information, such as splicing in words spoken in other contexts, or placing silent periods between words, leads to longer onset latencies which are more similar to the visual modality (Bentin, Kutas, & Hillyard, 1993; Holcomb & Neville, 1991; McCallum, Farmer, & Pocock, 1984). This pattern of results suggests that N400 latency varies lawfully with the time at which word information is externally presented.

A study investigating the resolution of lexical ambiguity in the visual modality also supports this conclusion (for a more complete description, see Van Petten & Kutas, 1987; 1991b). In that study, a 200 msec difference in the onset latency of the N400 elicited by words related to the contextually appropriate or inappropriate sense of ambiguous words indicated that the multiple meanings of ambiguous words are not simultaneously activated when they are preceded by a disambiguating context. Instead, the latency data suggested that the moment at which a particular meaning of an ambiguous word is activated is dependent on the time at which the relevant context is actually presented.

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[6]Note that since neither the cellular events underlying word recognition nor the generation of the scalp-recorded N400 are known, this is not a claim to a real-time record of the events yielding word recognition. Rather, since the waveshape and scalp distribution of the lexical and sentential context effects observed in the 300–500 msec latency window were the same, it is parsimonious to assume that they hear the same temporal relationship to the underlying neurophysiology.

In the present experiment, I used N400 latency to evaluate a temporal parameter which is internal to the language-processing system, namely whether two varieties of contextual information presented at the same time are applied with equal speed. No other studies have posed exactly this question, but a handful of results in the visual modality support the assumption that N400 latency can reflect such internal temporal parameters. In a word-pair experiment, Holcomb (1993) has shown that the peak latency of the N400 difference between related and unrelated words is prolonged when the target words are visually degraded, perhaps because visual pattern extraction is slowed under these circumstances. Kutas (1987; Kutas & Van Petten, 1990) has shown that the peak latency of the N400 difference between congruent and anomalous sentence completions is slowed when sentences are presented at a rate of 10 words per second. This experiment contrasted SOAs of 1150, 700, 250 and 100 msec and found a latency delay (of 100 msec) only at the fastest rate, which exceeds the average reading speed.

Kutas' (1987) results demonstrate the impact of what I have referred to as the first temporal parameter of rise time—time to digest the context—in showing a delay in the availability of sentential context when subjects are pushed above their normal reading speed. The present experiment was designed to answer a different question, i.e. whether a fully processed sentential context could be applied as rapidly as a lexical one. Speed of operation has been offered as a criterion for distinguishing modular from non-modular cognitive operations (Fodor, 1983). Since the sentential context effect observed here was no slower than the lexical effect, the data are not consistent with the idea that lexical context effects reflect the operation of a modular process and sentential context a non-modular one. Rather, the similar onset latencies suggest that both types of context were available and applied at the same time-point in the processing of the second words of the pairs. It is an empirical question as to whether there is some rate of sentence presentation which would yield a temporal dissociation in the application of sentential and lexical context. Eye-fixation studies suggest that, in natural reading, readers pace themselves so that they do not encounter new words until the previous ones have been interpreted as fully as possible (the "immediacy assumption"; Just & Carpenter, 1980). We might then predict that if such a presentation rate exists, it will be faster than natural reading speed, but this is a topic for further research.

As argued by Fodor (1983) and Swinney (Swinney, Zurif, & Nicol, 1989), functionally distinct processing modules should also be instantiated by different brain regions. To date, there have been few data to either substantiate or invalidate this claim with regard to a lexical processing system. In contrast to their high temporal resolution, scalp-recorded ERPs do not possess a high enough degree of spatial resolution to pinpoint their

neural generators without the use of adjunct techniques, such as the use of populations with focal brain damage, pharmacological manipulations, or comparison with magnetic recordings (see Schmidt et al., 1989; Smith & Halgren, 1989). Despite this consideration, ERP components do have replicable distributions across the head which are a complex reflection of the underlying generators. The initial phase of the sentential context effect (300–500 msec post-stimulus) observed here had a scalp distribution which was indistinguishable from the purely lexical context effect, contributing no supporting evidence to the idea that they arose in different brain regions.

Differences Between Lexical and Sentence Contexts

The lexical and sentential ERP context effects were not identical in the present data set. They shared a common phase captured in the measurement of a 300–500 msec latency window, but the sentential effect was more prolonged. In both types of congruent sentences, the difference between the first and second words of the critical pairs extended for at least an additional 200 msec beyond that observed in the Anomalous Associated sentences. Defining the set of circumstances which elicit this prolonged effect will require additional research. One possibility worth raising here is that the duration of the context effect reflects the amount of semantic detail retrieved for the eliciting word. Strongly associated words are usually related via their most salient or core semantic features, so that apprehending their relationship requires only a superficial semantic analysis. In the absence of any other context, this might be all that readers engage in, yielding a short-duration context effect. Within the context of a particular sentence, however, the reader might be encouraged to engage in more prolonged semantic analysis. A number of studies have suggested that the more peripheral aspects of a word's meaning become more or less salient depending on the context (Barsalou, 1982; Greenspan, 1986). For example, one of the current stimulus sentences was "He was trying to cut down on his *salt* intake so he used a lot of *pepper* and other spices". In isolation, or in an anomalous sentence, "salt" and "pepper" might be analysed as "two common substances for flavouring food", but the sentence suggests that one should differentiate the two by considering their sodium contents and the relationship between sodium and high blood pressure, etc. Perhaps it is this difference which accounts for the prolongation of the context effect in congruent sentences. Such a speculation might be tested by comparing ERPs to the same words embedded in contexts which refer to their prototypical or peripheral senses.

The second difference between the two varieties of context effect observed here was that the sentential effect demonstrated greater variability between subjects. Essentially every subject showed the lexical context effect, but the individual magnitude of the sentential effect varied from none to larger than the lexical effect. The amplitude of the sentential effect proved to be correlated with the post-sentence recognition task, suggesting some common basis for the ability to use sentence context and the recognition task. I would suggest that the commonality involves working memory. The recognition task clearly taps working memory, as does the ability to compile the individual words of an incomplete sentence into a conceptual whole that would aid in processing the next word. The exact nature of the relationship between these two functions of working memory could take any one of a number of forms, however. It may be that subjects with greater capacity are better able to perform both tasks, or that a reading strategy which emphasises the meaning of the sentence being read leaves greater capacity left over for the performance of the recognition task. Some measure of working memory capacity independent of the experimental tasks would aid in clarifying the nature of the relationship; this approach was used in a subsequent experiment (Van Petten et al., in prep.).

If Lexical and Sentential Context Effects Share a Common Mechanism, What is It?

The present results cast doubt on a two-processor model of context effects which attributes lexical/associative priming to automatic spreading activation within a lexicon and sentential context effects to a message-level processor. Other results have cast doubt on the idea of spreading activation as an explanatory mechanism even for lexical priming (Hodgson, 1991; Ratcliff & McKoon, 1981). There have been few alternative conceptions of priming mechanisms which consider both word-pair and sentence data. Ratcliff and McKoon have recently described a theory of priming which does not rely on spreading activation and which further attributes lexical and propositional context effects (e.g. those obtained in sentences or discourse) to a common mechanism. Some aspects of the present results and other N400 data seem to be well accommodated by this model, although other aspects do not yet have a niche.

In the "compound cue" model (Ratcliff & McKoon, 1988), the current word and prior context are combined into a "compound cue" which is then used to retrieve concepts from long-term memory. Context will aid in the retrieval of the current word's meaning if the compound cue is more highly associated with that meaning than the current word by itself. This model

unifies lexical and propositional context effects because the compound cue is constructed in working memory and can thus include higher-level propositions in addition to single-word meanings. The model is thus similar to spreading activation in suggesting that context facilitates the retrieval of semantic information, but differs in suggesting that word meanings in long-term memory do not possess "activation levels" which vary as a result of prior context and determine the accessibility of the word. Rather, the utility of the compound cue for retrieving a concept from long-term memory will determine the size of a context effect. The only difference between lexical and sentential context effects is the size and complexity of the compound cue formed in working memory. For lexical priming, the cue will consist of preceding individual words plus the current word; for sentential priming, the contents of working memory will also include the higher-order propositions formed from the individual prior words.

The compound cue model thus accommodates the present findings of a cumulative influence of sentence context on individual words (e.g. the word-position effect), and the similarity of the lexical and sentential context effects because the units of analysis are not single lexical entries but concepts. For a partially read sentence, the entire fragment to date could enter into the compound cue and aid in retrieval of the current word, although no single word in the fragment is related to that word.

In Ratcliff and McKoon's model, the primary determinant of the latency of a context effect is the time required to assemble the compound cue. This is the time I have described here as the first parameter of onset latency—"time to digest the context"—and is the parameter most closely linked with context–target SOA manipulations. The second parameter of onset latency, the one measured in the present experiment, would presumably be identified with the actual speed of the retrieval process in the compound cue model. If we were to identify the latency of the N400 with this later process, the present results would suggest that this time is constant regardless of the type of context entering the compound cue. However, other ERP studies have shown small variations in latency dependent on the type of context used (antonyms faster than category names: Kutas, pers. comm.; sentence fragments faster than single words: Kutas, 1993, this issue), so that a closer link between the model and ERP results will require a description of factors which can influence retrieval speed as well as the speed of cue assembly.

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APPENDIX

Each congruous sentence with an associated word pair is shown with the corresponding sentence containing an unassociated pair. The critical word pairs have been italicised.

1. She thought she should wear her *new* shoes but the *old* ones were more comfortable.
   Along with the promotion she was *allowed* to redecorate her *office* and hire an assistant.
2. Bob *drives* an enormous *car* so finding a space is always a problem.
   The *grinding* noise and *engine* overheating were caused by a loose fan belt.
3. She took the *baby* out when he started to *cry* and had to miss the rest of the movie.
   When there's an *earthquake* everyone should know how to *turn* off the gas supply and find the fuse box.
4. There were so many knots in her *hair* that it hurt to *comb* it.
   Halfway through their cross country drive Karen *remembered* the faucet in the *upstairs* bathroom.
5. The votes were evenly divided between *guilty* and *innocent* so they declared a mistrial.
   It is not legal for potential *employers* to *consider* a person's religion or race.
6. The hostess asked everyone whether they wanted *beer* or *wine* with dinner.
   The doctor stuck a thermometer in her *mouth* to *check* her temperature.
7. She was glad she had brought a *book* since there was nothing to *read* in the waiting room.
   She picked up a wallet on the *street* and was honest enough to *try* to locate the owner.
8. His lawyer warned him not to *sign* his *name* to anything without consulting her.
   The dictator destroyed most of the *ballots* from *areas* where his opposition was strong.
9. His roommate *answered* the *'phone* and said he'd be back later that evening.
   No one *wants* to *hire* a man who just got out of prison.
10. He put up a *picket fence* to keep the dogs in.
    The accident left an *ugly scar* on his forehead and scalp.
11. There are rules against *chewing gum* in school.
    She suffered from a *bad hangover* this morning.
12. He started to *cook dinner* but then got a 'phone call.
    The old gypsy *woman knew* Steve's future by reading his palm.
13. He had devoted his life to finding a *cure* for the *disease* that killed his mother.
    Her grandchildren first became concerned that she was *senile* when she *forgot* her social security number.
14. Every Sunday he *mows* the *lawn* and takes care of other household chores.
    They had been *married* a *year* and were already expecting their first child.
15. Dan *shaved* his *beard* and bought a conservative looking suit for the job interview.
    He *decided* to *travel* in Iran even though he knew it could be dangerous.
16. She did not have time to *vacuum* the *rug* before the dinner guest arrived.
    As soon as they reached the *sand* he *stopped* to take off his shoes.
17. I'll be spending Christmas at my *aunt* and *uncle's* house.
    The mechanic fixed the tire and *replaced* the *broken* spokes.
18. The *Democrats* seemed to focus on defense while the *Republicans* talked about the budget.
    His *lungs* were coated with black dust from his *years* as a coal miner.
19. The *pencil* broke and the *pen* ran dry.
    An *accountant* was hired to *check* the books.
20. He cracked the whip at the *lions* and *tigers* in the center ring of the circus.
    He asked them to deliver a *pizza* with *olives* and anchovies and ordered a sixpack too.
21. One of their presents was a *sterling silver* tea pot.
    The young Wall Street trader was *eventually convicted* of fraud.

22. He was one of the idle rich who could spend *summers* sunbathing and *winters* skiing.
    She always wished she could play an instrument but had *failed* miserably at *guitar* lessons.
23. The *dog* and *cat* got into a fight.
    They *discussed* the *topic* for the next class.
24. When someone suffers a heart attack the difference between *life* and *death* can be a matter of a few minutes.
    They were trying to decide between getting cable or *installing* a *radar* dish on the roof to improve the reception.
25. Eric and his wife sometimes take separate vacations since he likes to *hunt* and *fish* and she likes to shop.
    I sat far off to the side of the auditorium and my *line* of *sight* was blocked by a pillar.
26. Keeping a *cat* is a better way to get rid of *mice* than laying out poison.
    When I *called* the Department of Motor Vehicles I was put on *hold* for half an hour.
27. He was trying to cut down on his *salt* intake so he used a lot of *pepper* and other spices.
    The elderly couple's son had been a war *hero* and they kept his picture and his *medals* on the mantel.
28. The *schools* closed down because the *teachers* decided to go on strike.
    The *side* of the road was *covered* with bottles and other litter.
29. The candidate spent most of his funds on *radio* and *television* ads.
    For lunch he had a quarter pound cheese *burger* and *potato* chips.
30. Jane got her doctorate in anthropology for her work on the *myths* and *legends* of some Northwest Indian tribes.
    That project is not likely to be successful so you should *devote* your *effort* to something more worthwhile.
31. The *fire* broke out in the middle of the night and the house *burnt* to the ground.
    The *author* dedicated his first effort to all of the friends that had *encouraged* him to write.
32. She was tired of freelance *work* and wanted a secure *job* with a regular paycheck.
    The engineer couldn't stop in *time* to avoid hitting the *car* stalled on the tracks.
33. The *spider* sat in its *web* awaiting a fly.
    Every *spring* they hold the *annual* easter egg hunt.
34. He hadn't *paid* any of the *bills* so they cut off the electricity.
    She usually *walks* the last half *mile* to work from off-campus parking.
35. He decided to buy an IBM *computer* because many of his existing *programs* would be compatible.
    When she came back from the *restroom* she found him deep in *conversation* with the waiter.
36. In order to *prove* his *point* Ron staged a demonstration.
    She was too *impatient* to *stand* around and wait.
37. She *rode* a *bicycle* north up the coast to Santa Barbara.
    He *cracked* the *egg* so that he could separate the white and the yolk.
38. The hardest problem in restoring the ancient wooden *boat* was to find a craftsman who could still make *sails* out of canvas.
    He had been bitten by a wild *rat* and was concerned about the possibility that it was carrying *rabies* or the plague.
39. After taking his wallet they waved a *gun* and threatened to *shoot* him if he reported it.
    He had to file an official request *form* to drop the *class* because the deadline had passed.
40. The antique *chair* was beautiful but very uncomfortable to *sit* in.
    The magician *took* out his hat and made a *rabbit* appear.
41. They called a meeting in an attempt to *solve* the serious *problems* they shared.
    He tried to put the pieces of the *broken* plate back *together* with glue.

42. He had looked up that particular *word* many times but still couldn't remember how to *spell* it.
    He consulted a plastic surgeon to *learn* about the expenses and pain of getting a *nose* job.
43. At the end of the meal he was embarrassed to find that he had left his *credit card* at home.
    There is a new state law that restaurants have to post signs warning that alcohol can *cause birth* defects.
44. The visitors asked the head nurse if he had gotten *better* or *worse* during the night.
    While she was away her next door neighbor fed the *cats* and *watered* the house plants.
45. Just out of the corner of his *eye* he noticed that she was *winking* at him.
    There was no point in trying to *carry* on a conversation while the *band* was playing.
46. The professor said that they were due the last week of the quarter but Ken hasn't started *writing* his *paper* yet.
    Bob said he was on a diet but when he saw the chocolate cake he decided to *sample* a *little* bit.
47. Everytime we go to a Chinese restaurant Mary orders *sweet* and *sour* pork.
    The week after his skiing accident all his friends *signed* his *plaster* cast.
48. After her workout she wanted to take a *shower* and change into *clean* clothes.
    The tenants were evicted when they did not *pay* the last two *months* rent.
49. He took the rug with the *black* and *white* stripes to the cleaners.
    An architect must be able to *see* a *completed* project in three dimensions.
50. The almond orchard had *blossomed* but some sort of disease made the *flowers* wither.
    He went through every *inch* of the dog's fur with a fine *toothed* comb.
51. Their order was a long time coming so everyone filled up on *bread, butter* and other appetizers.
    The bicyclist had on tight black shorts and a helmet with a *rear view* mirror clipped on.
52. They captured some migrating *butterflies* and some *moths* on the field trip.
    I just had a *state* of the *art* sound system installed in my car.
53. The *hot* water tank sprang a leak so they had to wash everything in *cold* water.
    The *veterans* were suing the United States government because they had been exposed to *toxic* chemicals.
54. Fred *bought* the old house that was up for *sale* next door.
    A *lot* of Arizonans come to La Jolla to *escape* the heat.
55. After the divorce she had to move from a lush house in an *expensive* neighborhood to a *cheap* apartment.
    They scrambled to the top of the ridge to try to get their *bearings* since they were *hopelessly* lost.
56. The *tenants* decided to take their *landlord* to court.
    The *printer* didn't know how many *copies* to make.
57. His depth perception was so bad he couldn't tell if the lights were *near* or *far* away.
    It is a law that all of the emergency exits have to be *marked* in *case* of fire.
58. The company insisted that she have a urine test for *cocaine* or other *drug* use.
    Before she arrived he opened a bottle of Cabernet and *put* on some *classical* music.
59. It is a good idea to *brush* your *teeth* after every meal.
    The rebels wree secretly supplied with *arms* and *money* from our government.
60. He hung the *clothes* on the *line* to air dry.
    The stagnant green *pond* was a *breeding* ground for mosquitos.
61. She *locked* her car with the *keys* inside and had to break in with a coathanger.
    The *trial* was moved to a *different* state because of all the publicity surrounding the case.
62. His skin was red from *surfing* at the *beach* all day.
    The alcohol stung his irritated *skin* but he *needed* a disinfectant.
63. He blamed his lateness on the *freeway traffic* but this was just a convenient excuse.

They adopted the puppy from the *Humane Society* because Fido needed someone to play with.

64. The *sea gull* dove down and caught a fish.
The *raw sewage* was dumped straight into the ocean.
65. They settled for *domestic* champagne because the *imported* stuff was expensive.
By way of *apology* he sent a *dozen* long stemmed roses.
66. After the talk everyone had *cheese* and *crackers* with wine.
They use X-ray machines to *search* everyone's *luggage* for weapons.
67. Most drugs that induce *sleep* interfere with *dreaming* and result in worse insomnia.
The Red Cross provided *emergency* shelter and *supplies* for victims of the disaster.
68. I asked Chris to come *early* to help but of course he was *late* as usual.
The flag flew at half *mast* after the astronauts were *killed* in the big explosion.
69. He was so *tense* and *nervous* that his hands shook.
He filled the *glasses* with *champagne* and proposed a toast.
70. There were advantages to living in a *city* but Martha moved to a small *town* for the peace and quiet.
The biologist went to the desert every *week* to collect a particular *species* of lizard that he hoped to study.
71. When she was traveling in Britain she missed her strong black *coffee* but enjoyed the afternoon *tea* and scones.
There was a spill from an offshore drilling platform and many *birds* turned up coated with *sticky* crude oil.
72. He yelled when the *hammer* slipped off the *nail* and hit his thumb.
There was a rifle *rack* in the back *window* of the pickup truck.
73. The doctor was surprised that a man of eighty would have a full *head* of *hair* and good eyesight.
Her toothache had kept her up all night until she was able to *make* an *appointment* for the dentist.
74. He searched *high* and *low* for the address.
After being *robbed* the *victim* called the police.
75. The Reagans were preparing for a visit from the *King* and *Queen* of England.
He packed all the supplies for his fishing trip *including* a *lot* of beer.
76. When the *moon* is full it is hard to see many *stars* or the Milky Way.
When the *insurance* investigators found out that he'd been drinking they *refused* to pay the claim.
77. She could barely follow the movie over the *loud* conversation and finally asked the people to be *quiet* or move.
They had to turn back before reaching the *ski* area because they weren't carrying chains and the *plows* hadn't arrived.
78. The ranger warned them not to drink out of the *river* unless the *water* was boiled first.
The mill worker caught his hand in a piece of *machinery* and was *rushed* to the hospital.
79. He sanded out the *rough* spots so that the wood was *smooth* and level.
It was hard to *decipher* the address because the note was *crumpled* and faded.
80. They arrived *hungry* and *thirsty* and tired.
She had *lost* her *purse* and keys.
81. I hadn't realized that Paul and Katie were *husband* and *wife* because of their different last names.
Dave always buys mineral water because he doesn't *trust* the *stuff* that comes out of the tap.
82. After the hot spicy meal he complained of a *stomach ache* and had to lie down.
I thought he came on a motorcycle based on his *leather jacket* and helmet under his arm.
83. She put weather stripping around all the *doors* and *windows* to keep out the cold air.

We can't recommend that hotel because the *mattress* was *lumpy* and the room service was slow.

84. He took aspirin for the *aches* and *pains* of his arthritis.
He was convinced he was *receiving* radio *signals* from space aliens.
85. He seems taller because his *arms* and *legs* are so long.
The uranium miner had been *exposed* to *dangerous* levels of radiation.
86. Some people like to save every piece of wrapping paper but others like to *rip* and *tear* until the box is open.
It looked like a beautiful day as she was driving to work but by *lunchtime* the *sky* was dark grey and threatening.
87. This *insect* repellent keeps away most *bugs* including mosquitos.
The *flashlight* was useless once the *batteries* ran down.
88. She couldn't find a *scissors* so she *cut* out the ad with a razor blade.
The Eskimo was the *hero* of his *village* because he had killed a polar bear.
89. After his talk Fred was surrounded by a *crowd* of *people* with urgent questions.
They seem to build condos near every available *bluff* and *lagoon* in North County.
90. The man with the gun took it upon himself to be the *judge*, *jury* and executioner.
Most of their furniture was from a thrift store and they had *orange crates* for bookcases.
91. The *salad* consisted of a few shreds of wilted *lettuce* and one cherry tomato.
Mary *determined* to play matchmaker and set up a *blind* date between Carter and Helen.
92. All three were orphaned when their *mother* and *father* were killed in a plane wreck.
At a lot of parties people *tend* to *congregate* in the kitchen by the food.
93. She fixed the sticky drawer so that it *opened* and *closed* easily.
The hikers wanted to camp close to a *source* of *fresh* water.
94. He spoke out against civil rights for blacks and gays and billed himself as a *law* and *order* candidate.
One of the men in the nursing home refused to take his medication because it *made* him *feel* groggy.
95. Most American kids learn how to drive at sixteen when they are *juniors* or *seniors* in high school.
Not everyone is willing to explain a set of directions to a *foreigner* who *barely* speaks the language.
96. Lee can usually hit the basket but he can't *run fast* or play defense.
Whenever a frost is predicted the citrus growers light *smudge pots* in the groves.
97. It is hard to clean a fish without a good *sharp knife* and lots of water.
The harbor patrol fined the skipper for not carrying enough *life preservers* for everyone on board.
98. The *sky* was a clear *blue* because of the Santa Ana winds.
The *day* after the softball *game* he woke up with sore muscles.
99. The dining room set with the *table* and four *chairs* was on sale.
She found the steady drumming of *rain* on the *roof* to be soothing.
100. A *truck* had piled into a *car* in the fog and killed three people.
Both *players* were tired so they *quit* competing and just called it a tie.
101. His hair was naturally *dark* but the sun had turned it a *light* blond.
The basketball star had to *sit* out the season because of his *sprained* knee.
102. The hinges were rusted *shut* so he had to pry it *open* with a crowbar.
He can't be held *responsible* for the killing because he was *insane* at the time.
103. They had to stand in line at the *movie theatre* to buy tickets.
It is kind of tacky to leave the *price tag* on a gift.
104. There was *whipped cream* on the pie.
The wealthy *child attended* a private school.

105. Whenever there's *thunder* and *lightning* my dog hides under the bed.
This suntan *lotion* is *supposed* to screen out the harmful rays.
106. The war ended soon after the US dropped an *atom bomb* on Hiroshima.
Outside the front entrance of the museum was a *marble statue* of Venus.
107. After studying the map she realized they should have turned *left* instead of *right* at the light.
The union officials were worried about the long term health *hazards* of breathing *chemical* fumes every day.
108. I would much rather take an essay exam than have *true* or *false* questions.
After wandering in the marsh her shoes were not only *muddy* but *smelly* too.
109. Christmas was about the only time she saw her *sisters* and *brothers* and other relatives.
Her ex-husband had not paid alimony in several months so she *hired* a *detective* to find him.
110. He knew the hostess was allergic to *smoke* so he had his *cigarette* outside.
The cat had gotten into the sewing *box* so everything was a *tangled* mess.
111. The shirt he had been *given* didn't fit so he planned to *take* it back.
They had been wandering in *circles* without a compass before the rescuers *tracked* them down.
112. Jet lag is usually worse when travelling across time zones from *east* to *west* than the other direction.
They scrambled to the top of the ridge because they were *lost* and *hoped* to see some landmark.
113. Much of the *public* land in the United States is leased to *private* interests.
The fatal airplane *incident* was attributed to infrequent maintenance schedules and poorly *trained* mechanics.
114. He read the business section first thing every morning to decide whether to *buy* or *sell* or just wait.
Some scientists have been teaching sign language to chimpanzees to see what differences *exist* between *animal* and human communication.
115. She had to prove her competence in her *major* and *minor* fields.
He did not worry about burglars because he *kept* two *fierce* dogs.
116. The caterers had *baked* a delicious four layer *cake* for the occasion.
He bought some *poison* pellets to eliminate the *snails* from the garden.
117. There were no real *letters* only a lot of junk *mail* and bills.
He wasn't supposed to *repeat* their discussion to anyone without *top* secret clearance.
118. She had just *shampooed* her *hair* and it was still wet.
She occupied her *hours* by *knitting* scarves for all her grandchildren.
119. Her daddy had to *tell* her a *story* before she would go to sleep.
The jewelry that best *matched* the black *dress* was a single strand of pearls.
120. The *small* shoes looked cute in the window but they were torture for anyone with reasonably *large* feet.
The *volcano* became active for the first time in centuries and spewed ash all over the *neighboring* town.