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The effects of sentence topic and single word priming on lexical processing in connected speech

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THE EFFECTS OF SENTENCE TOPIC AND SINGLE WORD PRIMING ON LEXICAL PROCESSING IN CONNECTED SPEECH

by

Michelle A. Dunn

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, The City University of New York.

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Abstract

THE EFFECTS OF SENTENCE TOPIC AND SINGLE WORD PRIMING ON LEXICAL PROCESSING IN CONNECTED SPEECH

by

Michelle A. Dunn

Advisor: Walter Ritter Ph.D.

This research project explores the relationship, strength and time course of the effects of topic context and single word priming on the subsequent processing of lexical items in spoken language, through the use of behavioral and electrophysiologic measures.

A sample of normal, adults ranging in age from 25 to 49 years was studied. They had no history of learning or language difficulties.

The stimuli were single auditorally presented sentences. Each sentence was followed by a single probe word or nonword. Each real word was related to the preceding context in one of the following ways: 1) related to the sentence topic and not to the final word of the sentence; 2) related to the final word of the sentence but not to the topic; 3) completely unrelated to the sentence or to any of the words in it. Reaction time (RT) for making a lexical decision was used to index the degree to which the processing of a probe word had been effected by the preceding sentence or single word contexts. Contrast conditions were A) a lexical decision task utilizing all probes in isolation; B) a word pairs task in which all of the final words of the sentences were presented with their associated probes.

Electrophysiologic recording was done while 10 of the subjects performed the experimental tasks. Amplitude and latency measures of the N1, P2 and P3 components of the Cortical Event Related Potential (ERP) as well as mean amplitude measures of N4, were compared for all context conditions and probe types.

Reaction time data indicated priming of all probes which were related to the preceeding lexical or semantic context. Priming was strongest for probes related to sentence topic. In the ERP data, the negative complex peaking between 250 and 400 msec was largest for probes which were unrelated to their context and significantly attenuated for probes related to sentence topic. P3 latency results were consistent with RT findings. Interestingly, lexical priming effects were attenuated when a related prime-target word pair occurred in a sentence context as opposed to when it occurred in isolation. An unexpected finding was the enhancement of P2 for probes that were lexically related to their primes. This enhancement was seen whether the single word primes occurred in isolation or embedded in a sentence context.

The results of the present investigation lend support to the notion that both semantic and single word priming effect lexical processing in connected speech.

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INTRODUCTION

> Each word is doubly awakened; once from without by the lips of the talker, but already before that from within by the premonitory processes irradiating from the previous words and by the dim arousal of processes that are connected with the 'topic' of the talk.
>
> William James (1890, Vol.1, p.450)

Both empirical evidence and everyday experience support the idea that lexical processing is influenced by context. It is much easier to recognize a word heard in a noisy room or through static in a telephone line if this "degraded" material is heard in context rather than in isolation (Forster, 1976; Schuberth et al., 1981). Context can also be used to gain some sense of the meaning of a word we have not heard before as well as to aid in disambiguating words which have two or more meanings in isolation. Context can include the physical environment in which the utterance is heard, the speaker's tone of voice and knowledge of the speaker's intent as well as previously acquired knowledge concerning " the 'topic' of the talk" and the immediate linguistic context.

This project was designed to explore the effects of different types of linguistic context on lexical processing in connected speech. Three types of context effects have been studied extensively through behavioral cognitive/psycholinguistic studies and through electrophysiological research in linguistic processing. They are: 1) single word priming; 2) CLOZE probability as set up by the semantic and syntactic constraints of sentence contexts; 3) global topic context. There is considerable evidence supporting the notion that lexical access is influenced by associative (i.e., single word priming) contexts and that word recognition is affected by sentence and global topic contexts (Fischler and Bloom, 1979; Stanovich and West, 1979, 1981, 1983; West and Stanovich, 1982). A few attempts have been made both in the behavioral/cognitive and neurophysiology literature to directly compare associative level and larger linguistic context effects (Kleiman, 1980; Fischler, 1985; Nathan et al., 1989) but these phenomena have for the most part been explored separately. Little is known about how and under which conditions all of this contextual information is used in the processing of individual words in connected language and about the relationship of these effects in the same linguistic material. Specifically of interest for the present study is the relationship between the effects of single word/associative priming and topic priming on lexical processing in connected speech. It has been proposed that associative context only has an effect when the amount of time between the presentation of the prime and the target is brief or when there is less than one word intervening between the two. This model states that message level information facilitates word recognition (Simpson et al., 1989; Blank and Foss, 1978). Alternately, it has been argued that meaning is not integrated until after word recognition is complete. The facilitation effects that are seen with sentences are explained by the presence of strong lexical associates embedded in the connected speech which prime access of related words through spreading activation. It is thought that associative priming can in fact account for sentence context effects (Ratcliff, 1987).

It has not been documented that single word/associative effects are the same even when two related words occur adjacent to each other in a larger linguistic context, as when the same word pair occurs in isolation. In spoken language, the topic that the listener constructs over time may completely account for the facilitation of lexical recognition, overriding even the strongest lexical associates, or instead there may be an increment in the level of activation for all word meanings related to both the individual words that comprise the sentence and to the topic. Another view (Schwanenflugel and LaCount, 1988) is that topic context does not control the initial activation of a set of possible candidates for the word being recognized but that it acts rapidly to select among these candidates.

The aim of the present study was to provide support for the ideas that the enhanced lexical processing seen with sentence contexts cannot be accounted for solely by single word/associative priming and that in fact topic context modifies the effects of associative priming in connected speech. To this end, the effects of topic and associative contexts on lexical processing were explored in two parallel studies. The first was a behavioral study utilizing a lexical decision paradigm with reaction time as the dependent measure. The second involved the recording of Event Related Potentials (ERPs). While purely behavioral indices provide information about a process after the process is complete, electrophysiologic recording yields information regarding real time, on line cortical processing of linguistic material which cannot be derived from the results of a purely behavioral study. Comparisons among the ERPs in different experimental conditions can provide information regarding the timing of the effects of different types of context. ERPs provide a more direct index of the processes underlying lexical access in context than can behavioral measures. Due to the assumption that a behavioral response is more open to disruption by response factors, many investigators believe that the ERP is a more sensitive index of stimulus processing (Kutas, McCarthy and Donchin, 1977; Magliaro, Bashore, Coles, and Donchin, 1984).

Of particular interest in the present study is the so called N400 component. The N400 is thought to reflect semantic priming (Kutas and Hillyard, 1984). It has been shown in most cases that the amplitude of the N400 component covaries with reaction time in lexical decision and pronunciation tasks (Fischler et al., 1985).

LITERATURE REVIEW -

The first studies dealing with context effects were Taylor's CLOZE probability studies (1953). He presented readers with passages that had a number of words omitted. The subjects were required to fill in the blanks. He found that as context became more informative the overall variablity in readers' responses was greatly reduced. In the early 1960s Tulving and

Gold (1963) and Morton (1964) documented the semantic context effect by demonstrating that visual duration thresholds for an individual word on tachistoscopic presentation were significantly shortened when words were presented as the last word in a sentence context rather than in isolation. (It should be noted that all of the early investigations into semantic priming were done in the visual modality. To date this has remained the preferred modality of presentation, with very few studies being conducted auditorally.) Although the first research dealing with context utilized sentences, most of the initial investigations geared towards studying the effects of context on lexical processing, including access and retrieval, focussed on the effects of single word priming in word pairs and in lists.

1. Associative Level/Single Word Priming Studies-

These studies showed that the amount of time required to decide that a visually presented string of letters is a word as opposed to a nonword (lexical decision task) or to read a word out loud (pronunciation or naming latency task) was significantly shorter when that word was preceded by a related word than when preceded by an unrelated word (Meyer, Schvaneveldt and Ruddy, 1975). This finding was maintained whether the prime and target occurred as a word pair, as adjacent words in a list (Meyer and Schvaneveldt, 1971) or as two adjacent words embedded in a sentence (Blank and Foss, 1978). Reaction times in these tasks were also speeded by other types of association between prime and target, including similar sound or appearance (for written language) or syntactic usage (Caramazza, 1988).

It was later demonstrated that not only does context facilitate word recognition but when the prime and target are semantically unrelated this can slow or inhibit the processing of the target word relative to the speed with which it is processed in isolation. The processing of words related to semantic context can be facilitated in the absence of inhibited processing of unrelated words or both facilitation and inhibition can be present (Neely, 1977). For inhibition to occur, an expectancy for related targets must be developed over time; therefore, inhibition of unrelated targets is not seen at very short interstimulus intervals (ISIs) (100 msec or less) between prime and target. It has been proposed that inhibition of unrelated targets occurs at longer ISIs because initially an individual's attention is directed to lexical items which are related to the context. Attention must be redirected to the actual lexical item presented and this takes more time than to process the word in a purely bottom-up fashion, from the sensory features, when it is presented in isolation. In addition to dependence on the strength of semantic relationships between prime and target, the amount of facilitation and inhibition is influenced by the skill of the language user (Perfetti, Goldman and Hogaboam, 1979), the grade level (written language) (West and Stanovich, 1978) and factors in an experiment which foster various general semantic strategies as in studies of single word priming in lists (Fischler and Bloom, 1979; and Becker, 1980).

Blumstein et al. (1982) were the first to demonstrate auditory associative priming effects in a lexical decision paradigm. They collected normative data as part of a study of semantic priming through the auditory modality in patients with Wernicke's aphasia. The results of their normative study were reported to be quite similar to the effects found by Meyer and Schvaneveldt (1971) and Neely (1977) in the visual modality. This study is the only auditory word pairs study to date.

The findings of the single word priming studies concerning the relationship of facilitation and inhibition of single word processing led to the development of what has been referred to as "Two-Process Theories" which have to do with the role of attention in linguistic processing (Anderson and Bower, 1973; LaBerge and Samuels, 1974; Collins and Loftus, 1975; Posner and Snyder, 1975; Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). The most completely specified of these and the one that has had the most far reaching impact on subsequent research is that of Posner and Snyder. These theories state that access to long term memory is governed by two distinct processes, 1)automatic and 2)attentional/controlled. Automatic processing is characterized as rapid, seemingly effortless, places minimal demands on attentional capacity and is difficult to avoid. Controlled processing is slower, of limited capacity, effortful, and requires attention. The presence or absence of inhibition is seen as indicating process type. Facilitation and no inhibition of unrelated information is seen during automatic processing while both facilitation and inhibition are present during controlled processing. Purely automatic semantic priming has been demonstrated in the visual modality with brief interstimulus intervals (ISIs) (< or =100 msec) between prime and target. Controlled processing appears to come into play at longer ISIs (Neely, 1977).

Facilitation effects produced by associative context are generally interpreted to reflect the structure of semantic memory. Associative primes are thought to alter the state of related words in memory. The mechanism of this effect is held by most researchers to result from an automatic spread of activation between related lexical items (Collins and Loftus, 1975) producing a reduction in the word recognition threshold for those items. Although the actual mechanism of this activation is not known, there is little debate with the concept of spreading activation.

2. Syntactic and Semantic Context Provided by Sentences -

Individual words occurring in natural language contexts are not only subject to semantic but also to syntactic contraints. In the late 1970s investigations again began to focus on the effects of sentence contexts (Fischler and Bloom, 1979). There was a return to Taylor's (1953) CLOZE probability paradigm. Like single word priming, visually presented sentence contexts significantly influence speed and accuracy of lexical decision (Schuberth and Eimas, 1977; Fischler and Bloom, 1979; Kleiman, 1980) and pronunciation (Stanovich and West, 1979, 1981, 1983). Lexical decision and pronunciation tasks are the most widely used in experiments dealing with issues surrounding semantic priming, but phoneme and letter monitoring and probe word tasks have also been used extensively in the sentence context and discourse literature with similar results (Foss, 1980; Marslen-Wilson and Tyler, 1980). Initially the focus of this research was on the main issues brought up by the single word priming studies, specifically facilitation and inhibition of single word recognition by sentence context and allocation of attention.

Fischler and Bloom have done numerous studies looking at the effects of sentence contexts. Their 1979 study indicated that for adults (skilled language users) sentence context 1)facilitated the processing of words which were highly likely completions of a sentence (CLOZE probability >90%), 2)had no effect on congruent words with lower CLOZE probability and 3)inhibited classification of anomalous words. Of interest was the additional finding that subjects were unable to eliminate these context effects by trying to ignore the meaning of the sentence and just concentrate on making lexical decisions. They noted that sentence interpretation is extremely rapid and very difficult to avoid. They further explored these issues employing Forster's Rapid Sequenced Visual Presentation (RSVP) method (Fischler and Bloom, 1980). In this paradigm they varied the presentation rate of words to be read in sentences from a normal reading rate of 4 words per second to 28 per second. Even at the fastest rates priming effects, both inhibitory and facilitory, were seen. This was taken as an indication that general meaning can be obtained with little effort or conscious attention. However, the presence of inhibition effects was interpreted as indicating that sentence processing is neither totally automatic nor totally controlled.

One of the questions posed in this dissertation is whether the inhibition that is rapidly developed in sentence contexts can influence the automatic lowering of recognition thresholds for lexical associates to any one word in the context.

The mechanism of sentence context effects is strongly debated in the field. Some investigators propose that all sentence context effects can be accounted for by single word associative priming. In fact, the facilitative effect of a sentence context on the final word of that sentence is diminished if it does not contain strong lexical associates (Seidenberg et al., 1982; Stanovich and West, 1983). However, the effect is not completely eliminated and these studies are difficult to interpret as lexical association may be confounded with CLOZE probability. For example, a sentence such as "The captain walked on the deck." contains the strong lexical associates captain and deck and also has a high CLOZE probability. When the word captain is removed from this sentence and it becomes "The man walked on the deck." CLOZE probability is also decreased. The alternate view is that sentence context effects are related to the integrated message provided by the sentence (Simpson et al., 1989).

Although a global topic can be established within the confines of a single sentence, most work with sentence contexts has centered on CLOZE probabilities set up by the semantic/syntactic constraints of the sentence. This is in contrast to the far reaching effects of an established global topic and related knowledge that a particular individual has concerning that topic.

3. Global Topic Context -

Sentence contexts can prime subsequent linguistic material in more than one way. The semantic and syntactic constraints can prime for a particular word to come in a particular position within a sentence as in the CLOZE probability studies described in section 2 and they can prime through a global topic which is established within the sentence or a larger linguistic context. Cirilo and Foss (1980) observed that reading times are faster for lines that fill in lower level details for an already established central proposition or theme. Global topic context effects are far reaching and can facilitate processing for as long as the topic is maintained.

Although the Cirilo and Foss (1980) study was done in the visual modality, and almost all single word priming and sentence context studies have employed visual stimuli, most studies of discourse and the "on-line" processing of language have used spoken stimuli.

Studies of the global topic context effect have usually been done by psycholinguists to develop discourse models of natural language processing. In these models the specific concepts of automatic and controlled processing are not central, but the concepts of facilitation and inhibition still hold an important place. Interaction of lexical, semantic, syntactic and interpretive knowledge sources is stressed. These models posit that the listener or reader first constucts and then updates a semantic model and that this model is what is maintained (for as long as is useful) and employed to aid in the rapid interpretation of incoming information. The listener uses what has been termed by Clark and Haviland (1977) a "given-new strategy". The working model facilitates the processing of incoming information but is constantly checked for compatibility and consistency with the latest input. It does not predict what is to come, as conscious predictions would be wrong more often than right. The conceptualization of language processing put forth in the discourse models is very much in line with the Interactive Models of information processing and of auditory language processing (Marslen-Wilson and Tyler, 1981; Rumelhart and McClelland, 1986). These models hold that language comprehension is the result of a widely distributed pattern of activation that builds up over time as relevant meanings are enhanced and irrelevant meanings are suppressed. Within this framework, sentence context effects are viewed as emanating from many sources (ie lexical, semantic, syntactic, interpretive). The On-Line Interactive Model states that knowledge about the structure, meaning and intent of an utterance is acquired in parallel and interacts in real time during speech comprehension. The amount of information available from a particular knowledge source and its clarity determine the speed of processing of that information.

The parallel nature of the system makes it possible for information acquired from any one knowledge source to enhance the clarity of the information available from other sources.

4. Electrophysiological Studies Concerning Sentence CLOZE probability and Single Word Priming -

In the early 1980s the phenomenon of sentence context priming was addressed for the first time through investigations involving Event Related Potential (ERP) recordings of brain activity associated with certain kinds of language processing. Of direct relevance to the present investigation are the ERP studies of Kutas et al. (1980 a,b). These studies document that a negativity occuring at approximately 400 msec after stimulus onset (N400) "is reliably influenced by at least some of the factors previously shown to be effective in manipulating"

(Kutas and Hillyard, 1989) reaction time in semantic priming tasks. N400 was first reported by Kutas and Hillyard (1980 a,b). N400 is largest in response to the final words in sentences when they are semantically incongruous or of low CLOZE probability (Kutas et al., 1984). N400 amplitude is also sensitive to semantically anomalous words occurring earlier in a sentence (Kutas and Hillyard, 1983; VanPetten and Kutas, 1987), and to semantic inconsistencies in linguistic material with an individual's semantic knowledge (Fischler, 1983), learned 'episodic' information (Fischler et al., 1985) and self referential facts (Fischler et al., 1984). Therefore N400 is sensitive to semantic violations of the subject's knowledge about a given topic. The amplitude of N400 reflects the degree of semantic association between words and their context in that its amplitude varies as a function of the relationship between the semantic context provided and the target word.

N400 has been observed with auditorally presented sentences as well as visual ones (Holcomb, 1985; McCallum et al.,1986). However, only a few studies involving N400 have employed auditory stimuli. McCallum et al. observed a negativity peaking, somewhat later than in the visual modality, at 456 msec post stimulus onset, in response to the final word of a sentence when it was semantically incongruous. A physical change in the final word of a sentence, (suddenly switching from a male to a female voice) did not elicite this negativity but rather a positivity which they termed P416. This extended the findings of Kutas et al.(1980) to the auditory modality.

Some ERP studies have looked at the effects of single word priming on N400 while subjects made lexical decisions or category membership judgements (Bentin, McCarthy and Wood, 1985; Boddy, 1986). Late negativities appearing to be N400s, but somewhat more frontally distributed (Boddy, 1986) and generally smaller in amplitude than N400s in sentences contexts, have been observed. They are largest when they follow unprimed words in this context. Specifically, N400 is elicited by the final word in a four to seven word list when the word is from a different semantic category (Harben et al., 1984; Polich, 1985) and by the second of two unrelated words relative to the second of two related words (Boddy and

Weinberg, 1981; Bentin et al., 1985) Reduction in the amplitude of N400 and reduced reaction time on lexical decision were highly correlated in these tasks.

It has been proposed that the N400 waveform is related to word expectancy due to the fact that it varies as a function of CLOZE probability (Kutas and Hillyard, 1984). A number of N400 studies have been done in which semantic relatedness is not task relevant and therefore subjects were unlikely to build up expectancies (Fischler et al., 1983; Kutas and Hillyard, 1989). N400 has more recently been posited to reflect automatic spreading activation in the lexicon (Kutas et al., 1985; Boddy, 1986). This is doubted as the latency of N400 is well beyond what has been supported in the behavioral literature to be the period of exclusively automatic processing. On the other hand, it may be the case that automatic activation exists together with attentional processes at longer latencies after the initial processing of a word. Boddy (1986) did a study which claims that N400 reflects spreading activation in the lexicon. In a visual word pairs task where the subject was required to make a lexical decision to the second member in the pair, he manipulated the ISI between prime and target. Boddy found no difference between the amplitude of N400 at longer and shorter ISIs (0 msec vs 400 msec vs 800 msec). However behavioral studies have found that intervals longer than 100 msec are associated with stronger priming effects than those seen at ISIs of 100 msec or less in the visual modality (Neely, 1977). This has been attributed to attentional factors coming into play. Boddy interpreted the results of this study as indicating that only automatic activation contributes to N400, but this is suspect as this study is potentially confounded by ISI effects on the ERP which are unrelated to semantic activation. It is generally known that the early components of the cortical ERP are attenuated with shorter, relative to longer ISIs. The overall waveshape of the ERP has been shown to differ between longer and shorter ISI conditions. This has been attributed to both 1) the overlapping of the ERP elicited by the prime in short ISI conditions (<100 msec) and 2) the differences in brain potentials, at different ISIs, which develop in the time between stimuli when they are presented at a fixed rate (Rohrbaugh and Gaillard, 1983). Whether the changes seen in the

N400 with different ISIs can be attributed to these factors as well as semantic priming remains an empirical question; however, direct comparison of the N400 between conditions differing in ISI have been avoided in other studies (VanPetten and Kutas, 1987). The particular cognitive mechanism related to word recognition which underlies the N400 is unclear.

6. Relationship of Topic and Lexical/Associative Context -

The relationship of topic and single word/associative context in connected language has been explored through a few behavior/cognitive and ERP studies.

Becker (1980) demonstrated that in word lists the facilitative and inhibitory influence that a lexical associate had on its target was strongly related to the characteristics of the overall list. He found a facilitation dominant pattern (related targets facilitated with little inhibition of unrelated targets) for targets embedded in a word list where the strengths of the semantic relationships among the words on the list were consistent. He found an inhibition dominant pattern (unrelated targets inhibited with little facilitation of related targets) for targets when there was a wide range of semantic relationships represented in the list.

Particularly germane to the present investigation is a study in which Kleiman (1980) employed a sentence frame context requiring a lexical decision to the final word in each sentence. Reaction time (RT) was used as a measure of degree of semantic priming. He compared the facilitating effects of sentence contexts on three types of completions: 1) Words which were highly likely completions that had a high CLOZE probability (e.g., He was stung by a BEE.) 2) Other words that were acceptable completions but had low CLOZE probability (e.g., He was stung by a FISH.) 3) Words that did not form an acceptable completion but were strongly associatively related to the word with the high CLOZE probability for the sentence (e.g., He was stung by the FLOWER.). He found that: a) lexical decisions were fastest for words that were the most common completions; b) among words with low CLOZE Probability RTs were faster for words related to the most common completions than for words that were not; c) decision times were also faster for words that formed acceptable completions than for words that did not. Kleiman claims that relatedness and sentence acceptability are independant as the relatedness effect held even when the target words formed anomalous completions. This study supports the concept that both the semantic/syntactic constraints of the sentence and more local lexical/associative effects are involved in sentence processing, and that associates to a single word may be readily available even though they are not primed by the sentence context in which the word is embedded.

A few ERP studies have looked at sentence level and lexical/associative level effects and their relationship. Kutas et al. (1984) supported the findings of the Kleiman (1980) study just described using N400 as an index of semantic priming. Most importantly for the present study she found that the amplitude of N400 was smaller for words that formed anomalous sentence completions which were closely related to the expected completions than for anomalous completions that were not related. Fischler et al. (1985) studied the effects of associative (single word) priming context and context provided by knowledge of the topic in the same linguistic material. They compared ERPs for three types of sentences: 1)Correct statements with strong associations between the first word and the third and final word (e.g., Tuna are fish.) 2) Incorrect statements with strong lexical associations (e.g., Oysters are clams.) 3)Incorrect statements with unrelated words (e.g., Sardines are lips.) N400s for sentence type 2 were significantly larger than for sentence type 1 and significantly smaller than for sentence type 3. This study suggests that both single word priming and knowledge concerning topic may concurrently contribute to the contextual effect.

Kleiman (1980), Kutas et al. (1984) and Fischler (1985) support the idea that lexical/associative context can play a role in word processing in sentences. The strength and influence of this type of context in connected speech is unclear.

A few studies have explored the decay of semantic activation that has been produced through single word priming. Associative priming effects have been shown to diminish rapidly if there is a significant amount of time intervening between prime and target (Meyer, Schvaneveldt and Ruddy, 1977). In word pairs it has been demonstrated that a facilitation effect remains when a single unrelated word is inserted between a related prime and target (Schvaneveldt and Meyer, 1973) but disappears when more than one word is inserted. When word pairs are embedded in lists, if even a single word is placed between prime and target the effect is lost (Gough, Alford and Holly-Wilcox, 1981). Semantic Priming at the single word level appears to play a role in lexical access (Seidenberg et al., 1984) but associative links distant from each other in more complex linguistic material, specifically sentence contexts, appear to play little part (Foss and Ross, 1983; Carroll and Slowiaczek, 1986). Foss (1982) designed a study to assess the strength and time course of the decay of global topic and single word priming effects in sentences. Although his hypotheses that: 1) single word priming would have a very limited effect and 2) topic context would show little or no decay in priming for words which occur later if they are related to the high level topic of discourse are both appealing, this study was flawed. He looked at the facilitation of the second word in pairs embedded in sentences and in word level anagrams of those sentences. Foss's study was confounded by the fact that the tasks he used were not equated for processing difficulty making the results of the study extremely difficult to interpret.

Marslen-Wilson and Tyler (1980) have done very detailed studies looking at how what they termed local processing (word recognition) is influenced by more global processes (including syntax and message level interpretation) in assessing their "On-Line" interactive model. They used phoneme and category monitoring tasks in normal, semantically anomalous (but syntactically reasonable) and scrambled prose. The different probes were intended to assess how the various types of global context could facilitate or interfer with semantic processing (as in the case of the category probe) or lower level processing (as in the case of the phonetic probe). The results of their series of studies taken together support the general concepts of their model. One particularly important point that was supported is that the degree to which a discourse context has been established is directly related to the degree to which lexical processing is facilitated.

Simpson et al (1989) reported a series of studies which were modeled after Foss's auditory word recognition studies (1982). They too presented subjects with normal and scrambled prose contexts that contained strong lexical associates of the targets, but in this case the stimuli were visually presented and the task was simply to name the target words. This paradigm was chosen as it is accepted as being the best index of speed of lexical access in visual studies. This was a simple task for the subjects as evidenced by extremely low error rates in all conditions. The investigators found facilitation effects for related targets in normal sentences and inhibition for unrelated targets as compared to a neutral sentence condition. There were no effects for scrambled sentences or for semantically anomalous but syntactically correct sentences when the lexical associates were not adjacent. There was a mild facilitation when lexical associates occurred adjacent to each other in the contexts.

The literature cited here supports the idea that topic, sentence level and associative single word priming effects are all involved to some extent in lexical processing in connected language. However, as stated earlier, there is much controversy about how and under what conditions this occurs.

The issue being assessed through the present study is how semantic comprehension of individual words is influenced by the strength and relationship of global topic and single word priming contextual effects when presented in spoken sentences. Stanovich et al (1985) in a related study, put lexical/associative context in competition with the message level information provided by a sentence. They used sentences such as 'The farmer planted the tractor.' They found lexical and sentence level effects in children but no effects in adults. They speculated that the absence of priming effects in the adults was due to a speed accuracy trade off. There is an inherent difficulty with their paradigm in that when lexical priming and CLOZE probability were pitted against each other the sentences became semantically anomalous so that even if there was an associative effect it could be cancelled by the conflicting information.

The present study used natural, semantically appropriate, full sentence contexts. Strong lexical primes were present in some of them, in the final word position. The CLOZE probability for all sentences including the ones completed by the strong lexical associates was high (.70-.99). Probe words, presented after the completion of the sentences, were used to determine what word meanings were active in the lexicon at the time immediately following the presentation of the context. Probes were related to the topic of the sentence or only to the final word of the sentence, or they were unrelated to either.

8. Hypotheses-

It was postulated that:

1) Single words in context will prime adjacent words that are highly related (even when they are unrelated to the global topic context).

2) The effect of associative/single word context will be modified when associated lexical items are presented in a larger linguistic context as opposed to simply being presented in word pairs.

3) Priming effects as evidenced by reaction time and changes in the cortical Event Related Potential will be stronger for topic context than for single word/associative context when the lexical primes are embedded in sentences.

METHODS

1. Introduction and Overview

This investigation studied context effects on lexical processing in connected speech by normal adults. The initial study was a behavioral study which employed reaction time as the dependant measure. A second study employed Event Related Potentials (ERP) in an effort to examine some of the brain processes underlying the lexical priming effects.

Subjects were seen at the Albert Einstein College of Medicine, Bronx, New York for one testing session lasting approximately two and one half hours.

Three conditions were presented in both the behavioral and electrophysiologic studies:
Condition I - Sentence Context - On each trial a complete sentence was presented followed by a single probe word or nonword. Real words belonged to one of three probe groups:
1) related to the topic of the sentence but not to the final word of the sentence (e.g., His leaving home amazed all his friends. INDEPENDANT) ; 2) related to the last word of the sentence but not to the topic (e.g., At first the woman refused but she changed her mind. BRAIN); 3) unrelated to the topic and the final word of the sentence (e.g., He scraped the cold food from his plate. BOAT).
Condition II - Single Word Context - The final word of each sentence was presented followed by the probe word or nonword associated with it in condition I. In this case stimulus class "2" probes were related to their single word context whereas class "1" and "3" real word probes were unrelated.
Condition III - Isolated Words - Each of the probe words and nonwords was presented one after another without an antecedant priming word.

TABLE 1

CONDITION

PROBE TYPE	SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
1	WORD RELATED TO TOPIC	WORD UNRELATED	WORD
2	WORD RELATED TO FINAL WORD IN SENTENCE	WORD RELATED TO LEXICAL PRIME	WORD
3	WORD UNRELATED	WORD UNRELATED	WORD
4	NONWORD	NONWORD	NONWORD

The design of this study is shown schematically in Table 1.

In all conditions the subject was asked to make a lexical decision to the probe by responding to the real words. This paradigm was chosen because it makes it possible to assess which verbal associates are facilitated or inhibited by the preceding context after the final word of the sentence. The relationship and strength of single word priming and topic context as developed by sentences was explored by using the most probable single word associates to the global topic and to the final word of the sentence, as probe words. Most probable associates were determined through a normative study where 75 adults were asked to produce associates to each sentence topic and to the final word of each sentence presented in isolation.

For the three experimental conditions, one group of subjects (N=26) was run behaviorally and reaction time and error rate data were collected. Electrophysiologic recording was done concurrently with the behavioral tasks in a smaller group of subjects (N=10). Measurements of the amplitude and latency of the N1, P2 and P3 components of the cortical event related potential were taken. The mean amplitude of the N400 waveform within a specified latency range was used as an index of semantic priming as in earlier studies cited above.

2. Subjects

a) The subjects for the stimulus development procedure were 75 adults ranging in age from 25 to 49 years of age. They had no history of language problems or learning disability by self report.

b) Subjects for the experimental tasks were 26 adults ranging in age from 25 to 49 years also with no history of language or learning disability. Four of these subjects were male and twenty-two were female. All had normal hearing (save one subject who reported a mild high frequency hearing loss) and no history of neurological disorder.

c) Of the subjects tested with electrophysiologic recording two were male and eight were female. The handedness of these subjects was formally assessed. Two of the females were left handed and the rest of the subjects were right handed. The mean age of this group was 29.4 with a standard deviation of 4.33.

3. Stimuli

The stimuli were auditorally presented sentences each followed by a single probe word or nonword. Probe words and nonwords were balanced across all conditions for intensity and duration. Mean word frequency for the three real word probe lists was roughly equal and can be found in Table 2. Nonwords were all legal sound sequences in English and were easily pronouncible.

Sentences were chosen from from a list of 329 sentences normed for CLOZE probability by Bloom and Fischler in 1980. Only sentences with high CLOZE probability (.70-.99) were selected. Probe words were derived on the basis of the stimulus development procedure which is described below.

These stimuli were computer digitized natural speech and delivered by a female voice. Sentences varied in duration from 2000 to 3000 msec. All probe words and nonwords were edited to be 400 msec in duration. All stimuli were approximately 85 db SPL in peak intensity. They were delivered through headphones.

Natural speech was digitized and edited using the "Sound Edit" software package for the Apple Macintosh Computer. The stimuli were then sequenced with the "PictSnd" software program. Digital stimulus identification markers were generated by the "PictSnd" program and for the ERP study sent to a Nicolet Pathfinder signal averaging computer for tagging the EEG samples (single sweeps) associated with each stimulus presentation. This was done so that the single sweeps could be averaged offline according to various parameters.

TABLE 2

MEAN WORD FREQUENCIES FOR PROBE WORD TYPES 1, 2, AND 3.

1	2	3
6.26 % (Range - .20-27.80)	16.65 % (Range - .01-67.20)	5.55 % (Range - .01-51.60)

4. Testing Procedures

a. Stimulus Development Procedure

All subjects who participated in the stimulus development procedure were given 2 booklets, one containing 141 of Bloom and Fischler's sentences and the other containing 141 single words (the final words of the sentences, presented in isolation). Each stimulus had a blank space next to it. For the sentences the subject's instructions were "Read each sentence and write the first single word that comes to mind which is related to the overall meaning of the sentence." For the single words the subject was to "Read each word and write the first word that comes to mind in the blank provided."

The final stimulus list was comprised of 114 high Cloze probability sentences. Half of them had probes which were nonwords; the other half had real words. The real word probes fell into three categories with 19 probe in each):

1) One-third of the probe words were strongly associated with the overall meaning of the sentence. These words were those that were most frequently chosen by the normative sample as being associated with the sentence topics, but not associated with the final words of the sentences.

2) One-third of the probe words were strongly associated with the final word of the sentence but not with the sentence topic. These words were those most frequently chosen by the normative sample as being associated with each of the final words of the sentences, when the words were presented in isolation.

3) One-third of the probe words were real words which were not chosen as associates to either the sentence topics or to individual words by any of these 75 subjects (unrelated probes). This third group of probes was chosen randomly and roughly equated to the other two groups of probes for word frequency.

The final stimulus list is presented in Appendix A. All related real word probes are shown with their probability of association, which was calculated by dividing the number of people giving that word as an associate by the total number of people in the sample.

b. Behavioral/Electrophysiologic Testing Sessions

All subjects participated in 10 experimental runs. They were instructed to listen carefully to all stimuli and to lift the index finger of their dominant hand from a reaction time key as quickly as possible whenever the probe was a real word.

Each run had stimuli from all three probe type groups so that it is unlikely that any subject established different task strategies for different conditions.

Condition I - In the Sentence Context Condition, the subjects were told that they would be hearing a list of sentences. Each sentence would be followed by a word or a nonword. The task was to respond as quickly as possible when a real word was heard. The probability of hearing a word versus a nonword was 50%. The interval between the end of the sentence and the probe was 1000 msec. The time from the end of the probe to the beginning of the next sentence was always 3000 msec.

Condition II- In the Single Word Context Condition, the subjects were instructed that they would hear a list of words each followed by a word or nonword; again the task was to make a lexical decision. Half of the stimuli were real words and half were nonwords. The interval between each word and its probe was 1000 msec. The time from the end of the probe to the next word was 3000 msec. This condition was intended to show the difference in lexical priming when strong lexical associates occur together in isolation, not occurring in some larger linguistic context (i.e., a sentence).

Condition III - For the Isolated Word Condition the subjects were told that they would hear a list of words and nonwords and that they should respond to the real words. The ISI for this condition was 3000 msec. This condition was employed to show that there would be no significant difference in reaction times or the ERPs obtained for the three groups of stimuli when they were presented without context. The probability of hearing a real word as opposed to a nonword was 50%.

Condition III runs were always presented first. The order of administration of conditions I and II was counterbalanced across subjects. No sentence was presented more than once. Each of the probes was heard three times by the subject, once in each condition. Repetition effects on reaction time and on the ERPs were observed, but were equivalent across probe types. Repetition of stimuli effected RTs and ERPs equally in topic context and single word context conditions as a result of counterbalancing the task order.

5.Reaction Time and Feedback Procedure-

Reaction time was measured using a photocell key. The subjects were told to respond by lifting the index finger of their dominant hand from the key as quickly as possible whenever a real word was detected. Reaction times that occurred within two seconds after the onset of the probe word were accepted and recorded.

Periodically subjects were informed about their accuracy. In order to insure that the subjects were attending and processing the meaning of each sentence, at the end of each sentence run they were asked to recall as many of the sentences as the could.

6. EEG Recording and Processing

A Nicolet Pathfinder I Computer was used to record and analyze the ERP data. Grass gold cup electrodes were attached to the scalp with gauze and collodion at sites determined by the International 10-20 system. Sixteen channels of data were acquired. The following sites were used: F7, F3, F4, F8, left mastoid (LM), C3M (halfway between C3 and LM), C3, Cz, C4, C4M (halfway between C4 and RM), right mastoid (RM), T5, Pz, P4 and T6 all referenced to the tip of the nose. A Beckman biopotential electrode was placed above the right eye to monitor eye movements. The ground was placed at Oz.

The EEG was amplified 10K with a bandpass of 1 to 70Hz. The Nicolet Pathfinder I averaged the electrophysiologic signals off-line after each subject was run.

Analysis time was 2000 msec. The Pathfinder I was triggered to begin recording the EEG for an individual trial 200 msec before the onset of each probe word or nonword in order to obtain a prestimulus baseline against which amplitude measurements of the ERP waveform components could be taken. An artifact rejection program excluded epochs in which any sampled voltage exceeded ±100 uV.

7. Data Analysis

a. Behavioral Data

Speed of lexical decision as measured by reaction times served as a behavioral index of semantic priming. For the purpose of obtaining information about facilitation and inhibition effects these RTs were referenced to lexical decision RTs to the probes in isolation. Error rates in the different probe typess in the different conditions were calculated.

The mean reaction times of each of the 26 subjects seen as part of the behavioral study were entered into a 3 x 3 repeated measures analysis of variance with context type and probe type as factors. The Scheffe-F test (based on One-Way Repeated Measures ANOVAs) and Tukey HSD procedures were used to make post hoc comparisons between means. Analyses of the RT data involved comparisons across all three context conditions.

b. Electrophysiologic Data

The electrode sites where each component of the ERP was maximally present were determined for each condition through inspection of the grand mean waveforms. Baseline to peak amplitude measurements were taken at each of these electrode sites in individual subjects, for the first negative component (N1 - peak between 80 and 120 msec), first positive component (P2 - peak between 150 and 200 msec) and the P300 component (P3 - peak between 450 and 600 msec) of the cortical ERP. Peak latencies of these components were also measured. The negative complex occuring between 250 and 420 msec post stimulus onset (N400) was quantified by computer as the mean amplitude within a 150 msec window surrounding the peak of this negativity.

In the ERP data analyses, P3 amplitude and latency were compared across all three context conditions. N1, P2 and N360 (the peak of the N400 complex in the grand mean ERPs) were only compared in the Sentence and Single Word Context Conditions. The rationale for not making a direct comparison between the Isolated Word Condition and other context conditions for N1, P2 and N360 is as follows:

Effects of Different Interstimulus Intervals:

A direct comparison of the ERPs to stimuli presented in the isolated word condition with ERPs to the same stimuli in the sentence and single word context conditions was not made, due to differences in the intervals between the targets and the preceeding word (which were three seconds in the isolated word condition and one second in the other two context conditions). The interval between stimuli is known to influence the amplitudes of at least the early components (N1, P2) of the ERP. The effect of interstimulus interval (ISI) on the later components is unclear. The appropriate parametric study remains to be done but investigators (eg. VanPetten and Kutas, 1987) exercise caution and generally do not make direct comparisons among conditions utilizing different ISIs. Thus, in the present study ERP comparisons were made only when the ISIs were the same (i.e., in the sentence and single word context conditions).

Repetition Effects:

A direct comparison of the negative complex occurring between 250 and 400 msec (N4) obtained in response to stimuli in the isolated words condition was not made with the sentence or single word context conditions due to probable repetition effects. Rugg (1987) investigated the effects of stimulus repetition in a lexical decision task and found a significant attenuation of N4 to repeated words.

The issue of repetition effects did not prohibit comparisons between the sentence context and single word context conditions as the order of presentation of these two conditions was counterbalanced, so that all stimuli were repeated the same number of times.

Latency and amplitude measures of the ERP waveform components, taken at the electrode site where maximally present, were entered into separate repeated measures MANOVAs with context type and probe type as factors. Where a significant interaction was found between context and probe type, the Tukey HSD procedure was used to make post-hoc comparisons between means.

The Huynh-Feldt correction factor was used to adjust degrees of freedom where appropriate.

One-way repeated measures ANOVAs were also done to further specify the pattern of findings. The Scheffe-F test was again used to make post-hoc comparisons between means. In these analyses, both behavioral and ERP indices were compared for the different probe types within each condition and a comparison was made between the word pairs and sentence context conditions within probe type.

RESULTS

THE BEHAVIORAL STUDY -

Before proceeding with the statistical analysis of the data obtained through the behavioral study, all lexical decision reaction times that were outliers were removed from the database. Outliers were defined as reaction times that were more than two standard deviations from the mean reaction time on each task for each subject. Outliers were treated as errors.

The average percent of probe words correctly identified was 87 for the sentence context condition, 88 for the single word context condition and 82 for the isolation condition. Context appeared to aid subjects somewhat in correctly identifying probes as real words.

The mean reaction times of each subject (see Appendix B) were entered into a 3 X 3 repeated measures analysis of variance using context condition and probe word type as factors. The grand means for each task order group and the entire sample can be found in Table 3. (Refer to Table 1 for definition of probe types.) For the entire sample there were significant main effects of context $F(2,50)=22.4$, $p < .001$, and type of probe word $F(2,50)=67.4$, $p < .001$. There was also a significant interaction of context and probe word type $F(4,100)=15.4$, $p < .001$. Related probe words were responded to most quickly in the single word context condition and the slowest responses were seen for unrelated probe words in the sentence context condition.

The same analysis was also done separately for the two groups of subjects who received the two different task orders. For the group who heard the sentence context task before the single word context task, there were significant main effects for context $F(2,24)=21.5$, $p < .001$, and probe word type $F(2,24)=23.8$, $p < .001$. There was a significant interaction between the factors $F(4,48)=7.0$, $p < .001$. The same pattern was seen in the group

TABLE 3

BEHAVIORAL STUDY (N=26):
LEXICAL DECISION REACTION TIMES
MEANS AND STANDARD DEVIATIONS BY CONDITION AND PROBE WORD TYPE

Total Sample:

PROBE TYPE	CONDITION: SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
WORDS 1	606.1 (74.5)	595.1 (65.2)	600.8 (65.8)
WORDS 2	642.2 (83.4)	554.6 (59.8)	610.4 (71.5)
WORDS 3	702.9 (75.1)	644.9 (60.9)	626.9 (60.2)
NON-WORDS	———	———	———

Sentences First (N=13):

PROBE TYPE	SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
WORDS 1	592.2 (86.3)	573.3 (65.7)	591.3 (69.9)
WORDS 2	625.9 (91.6)	541.7 (52.1)	608.5 (90.7)
WORDS 3	703.4 (79.8)	620.2 (62.0)	622.2 (73.2)
NON-WORDS	———	———	———

Word Pairs First (N=13):

PROBE TYPE	SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
WORDS 1	619.9 (60.8)	616.9 (59.3)	610.4 (62.7)
WORDS 2	658.6 (74.4)	567.5 (66.1)	612.2 (50.5)
WORDS 3	702.4 (73.3)	669.6 (50.6)	631.6 (46.4)
NON-WORDS	———	———	———

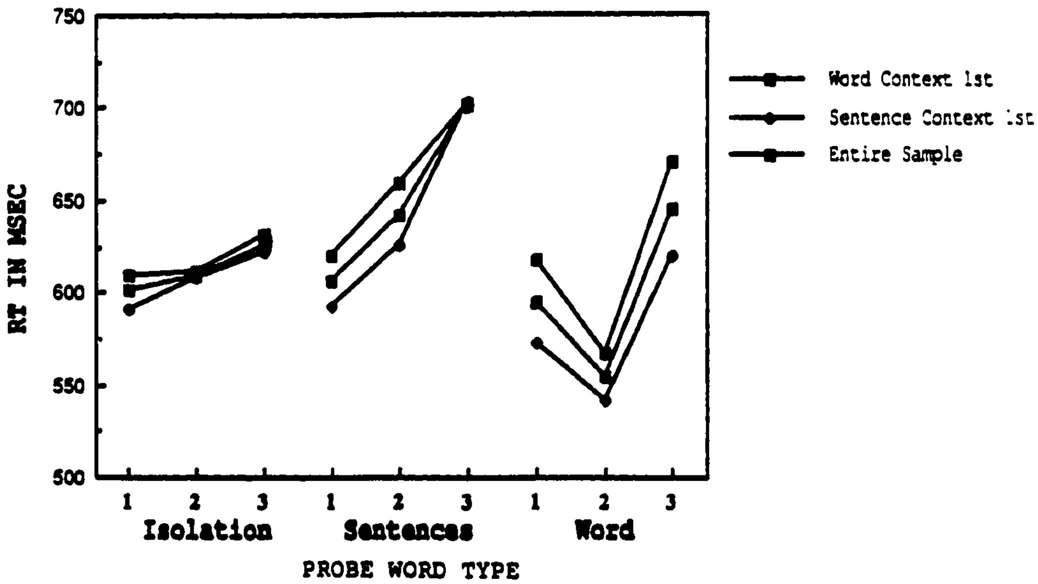


Figure 1. Mean reaction times by condition and Probe Word Type for the two task order groups and the entire sample.

receiving the single word context task before the sentence context task. The main effect for context was significant at the $p < .05$ level, $F(2,24)=8.8$, and the effect of probe word type was significant at the $p < .001$ level, $F(2,24)=56.5$. There was again a significant interaction $F(4,48)=9.3$, $p < .001$. There were no significant differences between the task order groups (see Figure 1).

Two-Way Comparisons-

Detailed analysis was carried out using the Scheffe F- Test and the Tukey HSD for comparisons within and between conditions. See Appendix D for a listing of significance levels associated with all individual comparisons.

As can be seen in Table 3, within the Sentence Context Condition, probes related to the sentence topic were responded to more quickly than those related only to the final word in the sentence, and than those which were completely unrelated to the preceding context. Words related to the final word in the sentence were responded to more quickly than unrelated probes. Two way comparisons showed that all differences between probe types within the sentence context condition were statistically significant.

In the single word context condition, reaction times for the three probe word types were significantly different from each other. Reaction times for probes which were related to the word that preceded, were shorter than for those probe words which were unrelated.

The powerful priming effect seen for related probe words in the single word context condition appeared to be disrupted by sentence context. Reaction time for related probes in the single word context condition was significantly faster than for the same group of words when presented in isolation. However, when the same prime target pairs were presented in a sentence context, with the prime embedded as the last word in the sentence, the lexical priming effect was attenuated. Responses to the probe words in these pairs were significantly longer in the sentence condition than in the single word context condition. There was not a significant difference in reaction time for these probes in the sentence context condition and in the isolation condition.

There was a significant prolongation of RT to unrelated probe words in the sentence context condition (Sentences 3) relative to when they were presented in isolation (Isolation 3). There was no significant difference in the speed of response to either probe type 1 or 3 (both unrelated to preceeding context) between the single word context condition and in the isolation condition. There was no significant difference in RT for probe words related to sentence topic context when presented in the sentence context condition (Sentences 1) and when presented in isolation (Isolation 1) ($p=.552$).

THE ERP STUDY -

Reaction Time Results -

The reaction time results of the 10 subjects who participated in the ERP experiment are shown in Table 4. They show generally the same pattern of significant differences as the 26 subjects run in the behavioral paradigm. Once again, see Appendix D for a listing of significance levels associated with all individual comparisons. The average percent of probe words correctly identified was 92 for the sentence context condition, 94 for the word pairs condition and 80 in isolation. As in the behavioral study, subjects accuracy improved with context.

ERP data associated with incorrect behavioral responses were not included in the analysis.

ERP Results -

A grand mean waveform for nonwords in the isolation condition is shown in Figure 2. This waveform is representative of the general morphology of individual subject's data for nonwords. In individual subjects all probe words and nonwords elicited a negative component (N1) ranging in peak latency from 88 to 112 msec post stimulus onset, followed by a positive component (P2) which peaked between 150 and 200 msec. The P2 was followed by an 'N4 like' negative complex between 250 msec and 400 msec with a peak latency of approximately

TABLE 4

ELECTROPHYSIOLOGY STUDY (N=10):
LEXICAL DECISION REACTION TIMES
MEANS AND STANDARD DEVIATIONS BY CONDITION AND PROBE WORD TYPE

Total Sample:

PROBE TYPE	CONDITION: SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
WORDS 1	553.2 (60.6)	566.0 (65.7)	577.2 (52.7)
WORDS 2	607.8 (56.7)	529.1 (58.3)	595.1 (57.4)
WORDS 3	676.0 (58.7)	627.8 (75.2)	612.5 (58.7)
NON-WORDS	———	———	———

Sentences First (N= 5):

PROBE TYPE	SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
WORDS 1	519.6 (47.1)	526.8 (44.4)	542.4 (17.5)
WORDS 2	572.8 (36.5)	509.2 (49.8)	571.8 (45.6)
WORDS 3	662.2 (68.3)	583.4 (45.1)	583.7 (50.5)
NON-WORDS	———	———	———

Word Pairs First (N= 5):

PROBE TYPE	SENTENCE CONTEXT	SINGLE WORD CONTEXT	ISOLATION
WORDS 1	586.8 (56.8)	603.8 (63.5)	612.0 (54.1)
WORDS 2	642.7 (53.4)	549.0 (64.7)	618.3 (63.6)
WORDS 3	689.7 (51.2)	672.1 (76.0)	641.2 (56.0)
NON-WORDS	———	———	———

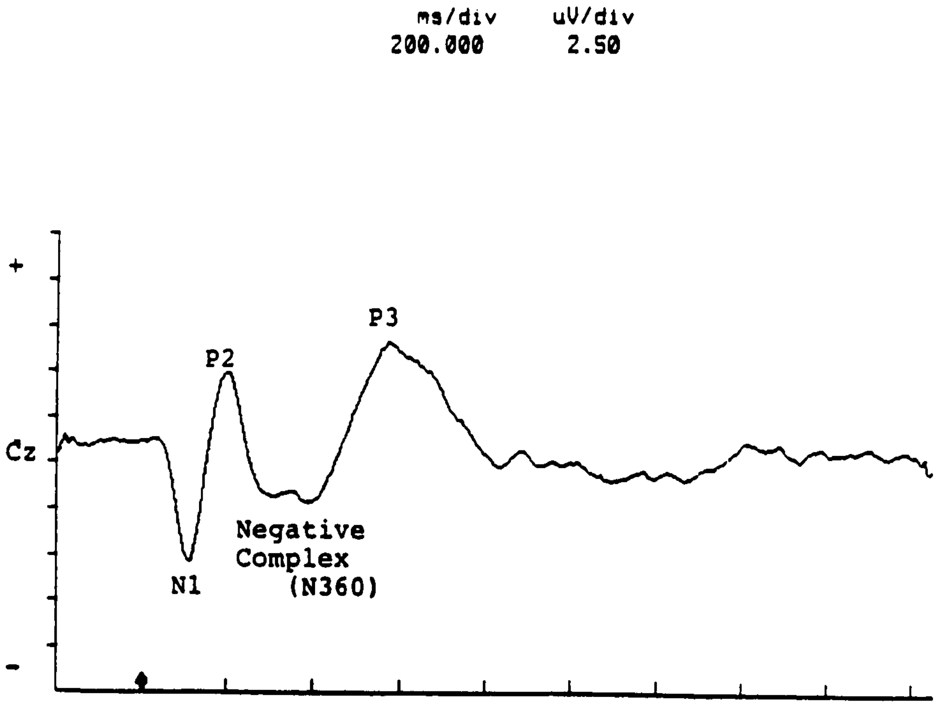


Figure 2. Grand Mean ERP with typical morphology. (Nonwords at Cz). Stimulus onset at arrow.

360 msec (N360). The amplitude of this negativity varied as a function of the semantic relatedness of the probe word to the previous context, with nonwords and unrelated targets eliciting the largest negativity. This negative complex was followed by a positivity (P3) peaking between 450 and 600 msec. The grandmean waveforms for all 16 electrode sites across all subjects for all conditions are shown in Appendix C.

Grand mean ERPs elicited by probes in all conditions are presented, superimposed, for the Cz and P3 recording sites in figures 3a-3c. Inspection of the grand mean ERPs and individual subject's data revealed that the N1, P2, and N360 components of the ERP were largest at Cz. P3 amplitude in response to nonwords was maximal at Cz while P3 amplitude in response to real words was greatest at the left parietal electrode (P3). Thus, latency and amplitude measures of N1 and P2 and mean amplitude measures of N360 were taken at Cz. Amplitude and latency measures obtained at the left parietal electrode as well as at the vertex were entered into the statistical analyses of the P3 component.

Analysis of ERP Components for the Isolated Word Condition -

The isolated word condition was employed to show that there were no inherent differences between probe words (1,2,3) which affected the ERP (see Tables 5-9). Thus any differences within the sentence or single word context conditions could reasonably be attributed to the manipulation of the independent variables. Inspection of the superimposed grand mean waveforms elicited for each probe type (see Figure 3c) revealed no differences in N1 or P2. One-Way repeated measures ANOVAs indicated no significant differences in the amplitudes or latencies of N1, P2, N360 and P3 for real word probes (1,2,3). Nonwords elicited ERPs that differed significantly from those elicited by real words. P3 latency was significantly longer for nonwords than real words at both Cz and P3 ($F(3,24)=7.12$, $p=.001$). P3 amplitude was significantly larger for real words than nonwords at the left parietal electrode ($F(3,24)=3.34$, $p=.05$). Although not statistically significant, a slightly enhanced P3 for nonwords over real words was observed at Cz. The amplitude of N360 also differed

200.00 msec/div 2.50 microvolts/div

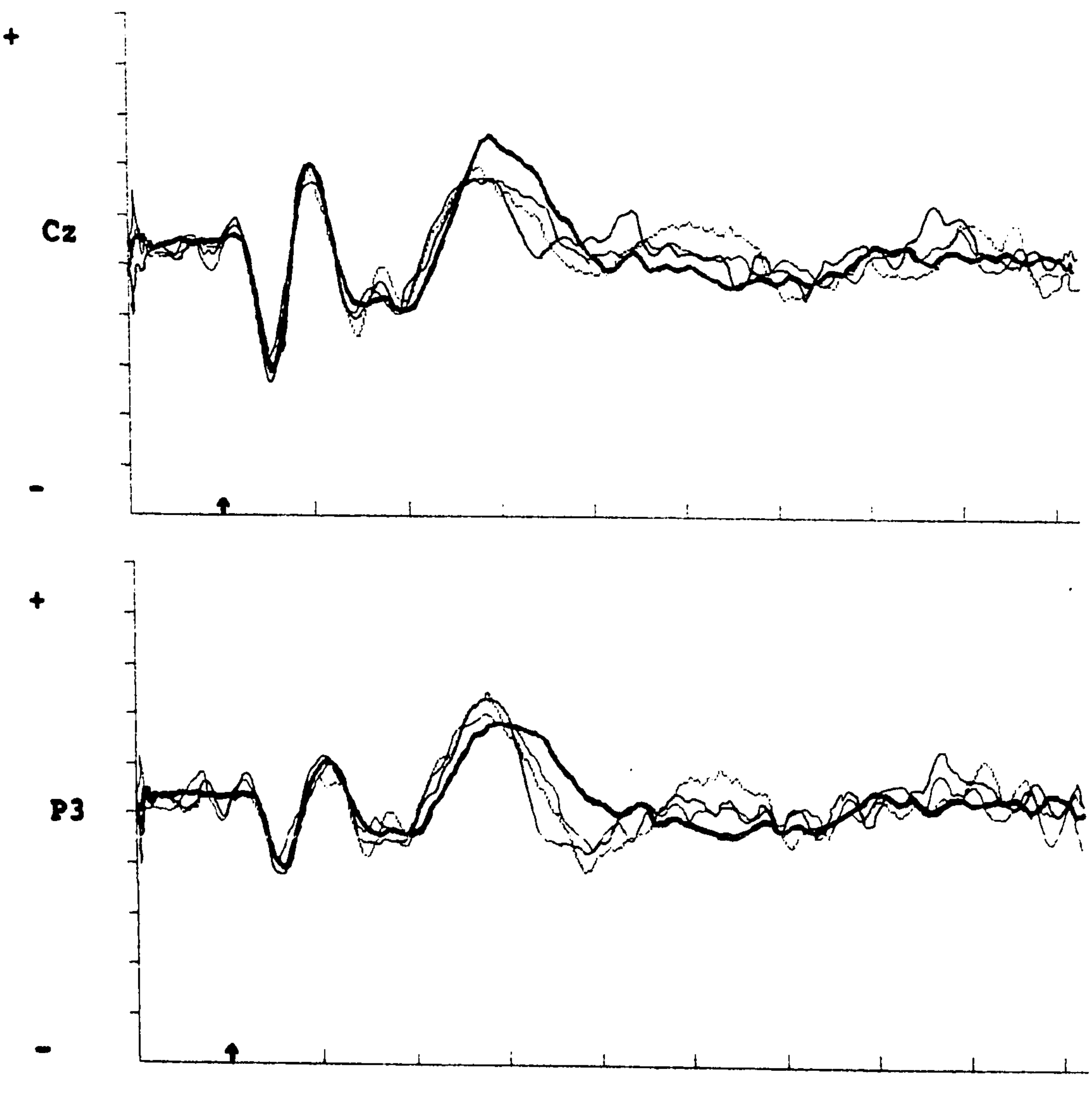


Figure 3a. Isolated Words Condition - Grand Mean ERPs for Probe Words 1 (Blue), Probe Words 2 (Grey), Probe Words 3 (Red), and Nonwords (Green) at Cz and P3. Stimulus onset at arrow.

200.00 msec/div 2.50 microvolts/div

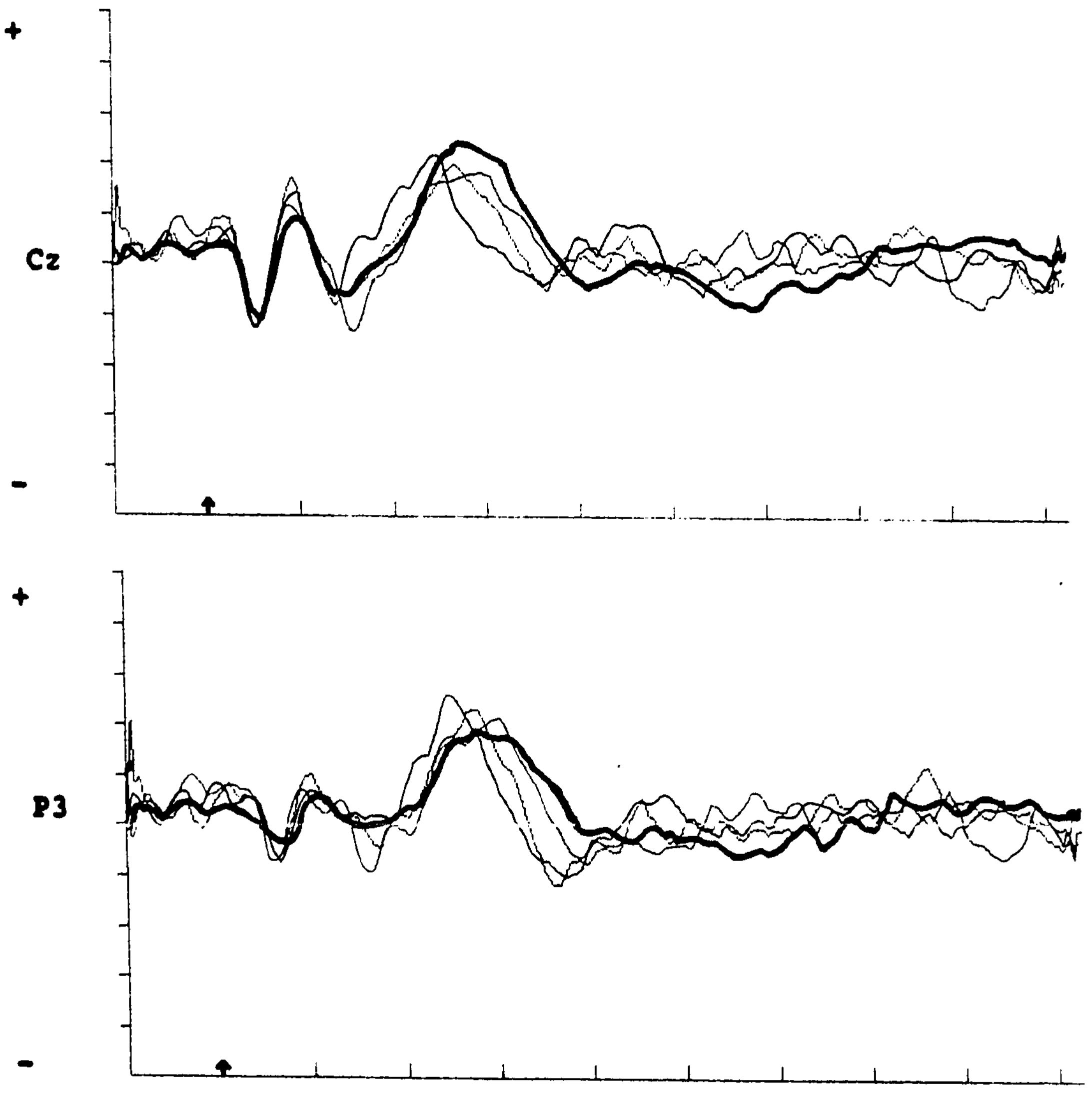


Figure 3b. Sentence Context Condition - Grand Mean ERPs for Probe Words 1 (Blue), Probe Words 2 (Grey), Probe Words 3 (Red), and Nonwords (Green) at Cz and P3. Stimulus onset at arrow.

200.00 msec/div   2.50 microvolts/div

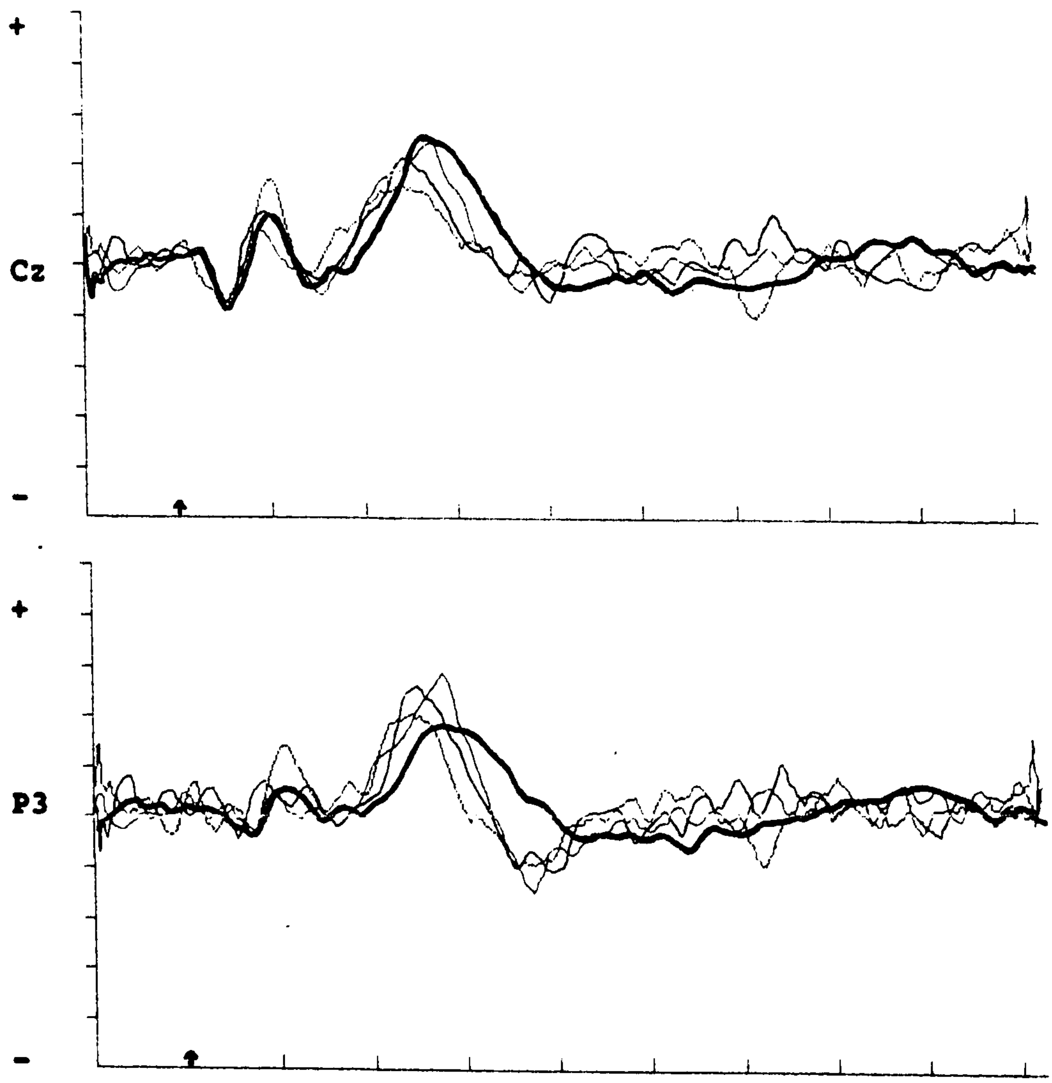


Figure 3c. Single Word Context Condition - Grand Mean ERPs for Probe Words 1 (Blue), Probe Words 2 (Grey), Probe Words 3 (Red), and Nonwords (Green) at Cz and P3. Stimulus onset at arrow.

TABLE 5

MEAN AMPLITUDES OF THE N1 AND P2 COMPONENTS AT Cz FOR THE ISOLATED WORDS TASK BY PROBE TYPE

Component		Real Words 1	2	3	Nonwords
N1	$\bar{X}$=	-6.90	-6.40	-6.01	-6.16
	s=	2.68	2.02	3.00	1.79
P2	$\bar{X}$=	5.34	4.20	4.37	4.57
	s=	1.99	1.88	1.58	1.19

TABLE 6

MEAN LATENCIES OF THE N1 AND P2 COMPONENTS AT Cz FOR THE ISOLATED WORDS TASK BY PROBE TYPE

Component		Real Words 1	2	3	Nonwords
N1	$\bar{X}$=	100.0	100.0	100.8	102.4
	s=	6.8	8.6	7.7	6.3
P2	$\bar{X}$=	184.0	188.0	186.4	191.2
	s=	13.1	12.1	13.1	10.3

TABLE 7

MEAN P300 AMPLITUDE AT P3 and Cz FOR
THE ISOLATED WORDS TASK BY PROBE TYPE

Electrode		Real Words 1	Real Words 2	Real Words 3	Nonwords
P3	$\bar{X}$=	6.00	5.91	5.78	4.75
	s=	1.59	1.15	1.78	1.72
Cz	$\bar{X}$=	5.42	5.44	5.45	6.11
	s=	1.85	1.07	1.58	1.72

TABLE 8

MEAN P300 LATENCY AT P3 and Cz FOR
THE ISOLATED WORDS TASK BY PROBE TYPE

Electrode		Real Words 1	Real Words 2	Real Words 3	Nonwords
P3	$\bar{X}$=	548.0	546.7	552.0	591.2
	s=	28.3	20.8	26.5	33.8
Cz	$\bar{X}$=	549.7	549.0	550.2	580.0
	s=	14.4	16.5	26.5	33.2

TABLE 9

MEAN N360 AMPLITUDES ACROSS SUBJECTS FOR THE ISOLATED WORDS TASK

Electrode	Real Words 1	Real Words 2	Real Words 3	Nonwords
T5	-.461	-.277	-.356	-.601
C3M	-.526	-.463	-.552	-2.217
C3	-.661	-.543	-.572	-2.780
Cz	-.675	-.419	-.645	-3.026
C4	-.642	-.519	-.463	-2.833
C4M	-.627	-.449	-.470	-2.608
T6	-.460	-.309	-.267	-1.457

significantly for real words and nonwords, being larger for nonwords (F(3,21)=87.94, p=.001). (Please see Part 7 of the Methods Section for a rationale for not making direct comparisons of N1, P2, or N360 in the Isolated Words Condition and the other context conditions.)

Analysis of ERP Components for the Sentence and Single Word Context Conditions -

A series of two factor repeated measures MANOVAS were run using within subject means of the amplitudes and(or) latencies of the different ERP components as the dependent measures. It was decided that a separate MANOVA be run for each dependent measure so that individual subjects with missing data could be included in analyses for which they had data rather than completely excluding them from the analysis. Degrees of freedom were adjusted with the Huynh-Feldt procedure to compensate for inhomgeneous variances. The following analyses were performed on ERPs obtained for stimuli in the single word and sentence context conditions.

N1 -

There were no significant differences in the peak latency of N1 across or within conditions (see Table 10) nor were there significant differences in the amplitude of N1 (Table 11).

P2-

There were no significant differences in the peak latency of P2 (Table 10). However, a 2 x 4 repeated measures MANOVA with context type (sentences vs. words) and probe type as factors indicated a highly significant main effect of probe type on P2 amplitude F(3,27)=5.98, p=.003. This main effect reflected the enhancement of P2 amplitude for probes preceeded by a lexical prime. This was a completely unexpected finding. There was no main effect for context condition and there was no interaction. The Scheffe-F test procedure for comparisons among cell means indicated that when the probe word was primed by a single

TABLE 10

MEAN LATENCIES OF N1 AND P2 COMPONENTS AT Cz
FOR THE SENTENCE AND SINGLE WORD CONTEXT CONDITIONS

Component		Sentence Context 1	2	3	Nonwords	Single Word Context 1	2	3	Nonwords
TOTAL SAMPLE (N=10)									
N1	$\bar{X}$=	99.2	99.2	99.2	98.4	93.6	91.2	96.0	96.0
	s=	12.0	12.0	7.7	10.7	7.6	12.6	19.2	8.4
P2	$\bar{X}$=	180.8	183.2	181.6	188.8	176.0	189.6	174.4	184.8
	s=	15.2	13.3	13.1	13.7	17.7	12.5	22.6	17.9

TABLE 11

MEAN AMPLITUDES OF N1 AND P2 COMPONENTS AT Cz FOR SENTENCE AND SINGLE WORD CONTEXT CONDITIONS

		Sentence Context				Single Word Context			
		1	2	3	Nonwords	1	2	3	Nonwords
Component									
WORD PAIRS FIRST (N=5)									
N1	$\bar{X}$=	-5.65	-4.31	-3.76	-3.24	-2.94	-3.05	-3.55	-2.70
	s=	2.36	2.05	1.74	1.46	1.06	1.59	2.20	0.87
P2	$\bar{X}$=	3.26	3.06	3.47	2.11	2.62	4.26	3.19	2.07
	s=	1.85	1.06	2.07	0.34	1.89	2.69	2.00	1.11
SENTENCES FIRST (N=5)									
N1	$\bar{X}$=	-3.90	-4.03	-3.78	-3.90	-3.74	-4.45	- 3.45	-3.66
	s=	1.92	0.96	1.45	1.18	1.29	0.90	1.10	1.16
P2	$\bar{X}$=	3.43	5.22	2.35	2.15	3.37	3.89	1.95	2.30
	s=	2.20	2.22	1.25	1.16	0.98	1.19	0.43	0.91
TOTAL SAMPLE (N=10)									
N1	$\bar{X}$=	-4.80	-4.17	-3.77	-3.57	-3.34	-3.75	-3.50	-3.18
	s=	2.24	1.52	1.51	1.30	1.19	1.43	1.64	1.09
P2	$\bar{X}$=	3.34	4.13	2.91	2.13	2.99	4.08	2.52	2.04
	s=	1.92	1.99	1.72	0.81	1.47	1.97	1.84	1.27

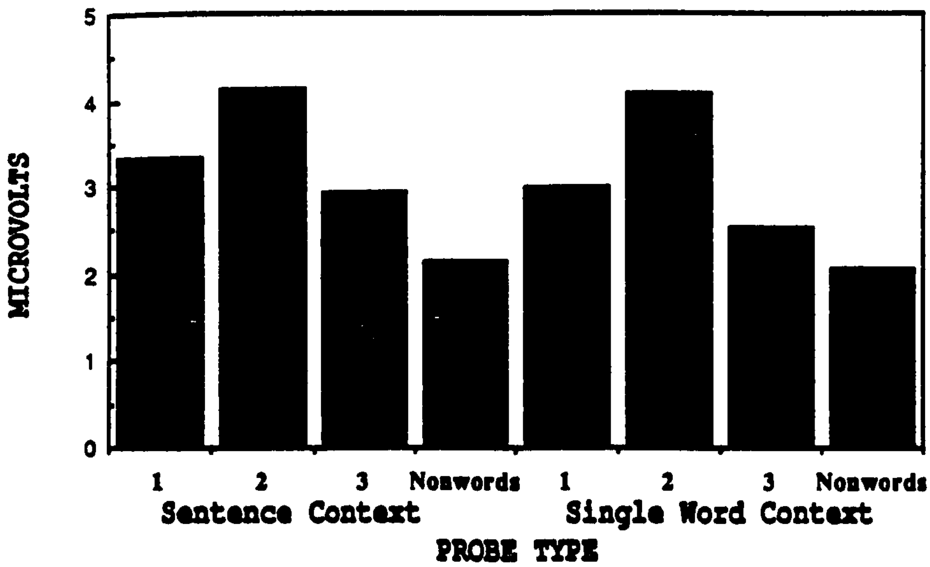


Figure 4. Mean Amplitudes of P2 for Sentence and Single Word Context Conditions.

word associate there was a significant enhancement of P2 amplitude to words, relative to nonwords, in the sentence and single word context conditions (see Table 11). The superimposed waveforms shown in Figures 3a and 3b depict the differences between probe types within context conditions. Figure 4 illustrates the differences in P2 amplitude for the different probe types in the sentence and single word context conditions.

N360 ('N4') -

The peak of N360 at Cz (between 250 and 400 msec) was determined for each subject. The mean amplitude of this negative complex was measured over a 150 msec window beginning 75 msec before the peak and ending 75 msec after. The same latency window was used to measure N360 at the other electrode sites as well (see Table 12). Each subject's mean amplitude data at Cz, for all conditions was entered into a 2 X 4 repeated measures MANOVA with context type (sentences vs words) and probe type as factors. There was a significant main effect for probe type $F(3,24)=3.88$, $p=.02$. There was no main effect for context and there was not a significant interaction. Because there was not a significant interaction, a more detailed analysis of the differences in N360 associated with different types of probe words was undertaken by entering the N360 data into two separate One-Way repeated measures ANOVAs (one within the sentence context condition and one within the single word context condition).

Two-Way Comparisons-

The Scheffe F-test procedure was again used to make comparisons of cell means within conditions. The superimposed waveforms in Figures 3a and 3b depict the differences within each context condition. N360 elicited by nonwords was substantially larger than that seen for the words. In the sentence context condition N360 was attenuated for the probes related to sentence topic relative to that seen for the last word of the sentence ($p=.01$) and for that seen with the unrelated probes ($p<.001$). N360 to probes related to the last word of the

TABLE 12

MEAN AMPLITUDES OF N360 ACROSS SUBJECTS BY CONDITION

	Sentence Context				Single Word Context			
	1	2	3	Nonwords	1	2	3	Nonwords
Electrode								
T5	-.145	-.251	-.310	-.364	-.253	+.051	-.120	-.434
C3M	-.251	-.358	-.385	-1.534	-.242	-.052	-.176	-1.295
C3	-.189	-.349	-.533	-1.730	-.276	-.047	-.252	-1.223
Cz	+.317	-.335	-.541	-1.580	-.120	+.129	-.163	-1.036
C4	-.133	-.292	-.487	-1.671	-.219	+.076	-.230	-1.344
C4M	-.294	-.278	-.429	-1.331	-.163	+.036	-.194	-1.423
T6	-.148	-.188	-.297	-.364	-.207	+.131	-.057	-.589

sentence was attenuated relative to that elicited by unrelated probes ($p=.05$).

In the single word context condition there was no significant difference in mean amplitude between N360s to probes in stimulus classes 2 and 3, which were unrelated to the primes. Probes which were related to their primes in the word pairs condition were associated with what appears in Figure 3c to be an attenuated N360. However, this difference is not significant.

Figure 5 depicts the differences in N360 amplitude between context conditions within stimulus groups. The amplitude of N360 is significantly increased when an associatively related prime-target pair is embedded in a sentence relative to when the same word pair occurs in isolation.

The analysis of task order groups showed the pattern described above for the entire sample with one interesting exception. Four of the five subjects who received the sentence context condition first, differed from the group that received the single word context condition first. For these subjects the mean amplitude of N360 to the type 1 probes in the single word context condition (unrelated) was smaller than the N360 to the type 3 probes (also unrelated). N360 was attenuated for probes that had been related to the sentence topic in the previously presented condition. N360s for probe types 1 and 3 were the same amplitude for the group of subjects receiving the single word context first. Figure 6 shows the average amplitude of the N360 across each of the two task order groups and across the entire sample.

P3 -

Amplitude -

Two separate 3 x 4 repeated measures MANOVAs run on P3 amplitude measures collected at the Cz and P3 electrode sites indicated no main effects for context or probe type and no significant interaction. One-way repeated measures ANOVAs done within each context condition (sentence and single word) indicated a marginally significant difference between P3 amplitude for words and nonwords in the single word context condition. As in

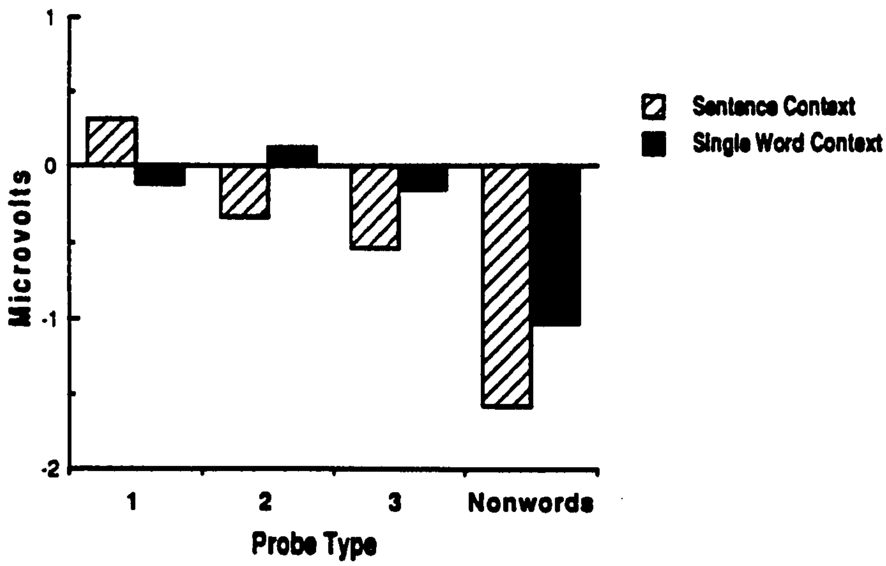


Figure 5. Mean Amplitudes of N360 in Sentence and Single Word Context Conditions.

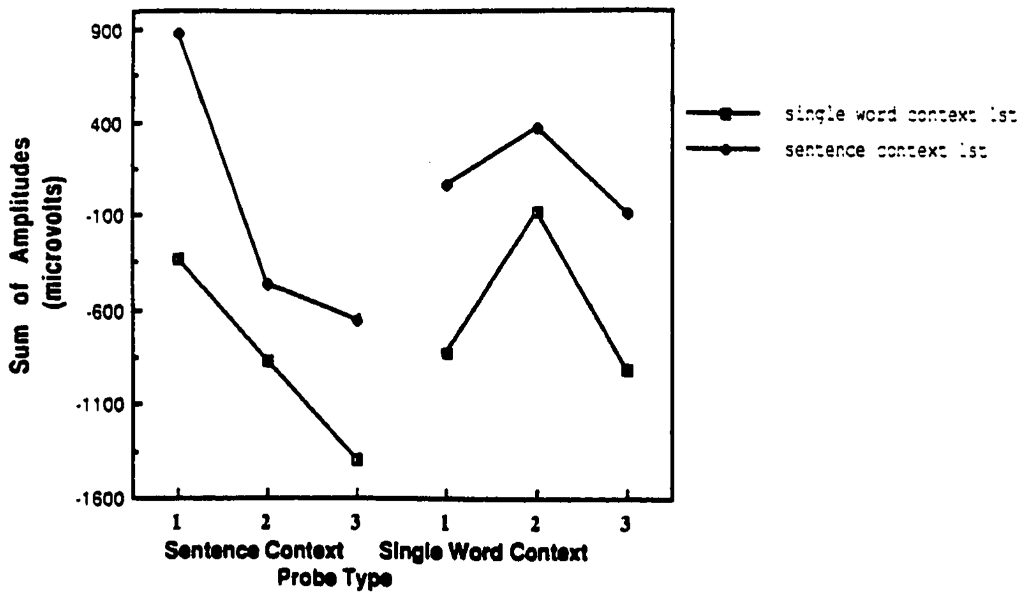


Figure 6. Sum of Amplitudes of N360 within a 150 msec time window (defined as beginning 75 msec before and ending 75 msec following the peak of N360) for two task order groups.

the isolated words condition, the amplitude of the P3 component was significantly larger at P3 for real words than for nonwords ($p=.05$) in this condition. There was no significant difference for P3 amplitude across probe types in the sentence context condition. Mean P3 amplitudes and standard deviations by condition are shown in Table 13. There were no significant differences in P3 amplitudes within probe types across conditions.

Latency -

Mean P3 latencies are shown in Table 14. P3 latency measures were entered into a 3 x 4 repeated measures MANOVA with context condition (all three levels) and stimulus class (4 levels) as factors. There was a main effect of context $F(2,16)=9.91, p=.002$, (P3 latency was earliest in the single word context condition and longest in the isolation condition). There was a main effect for probe type $F(3,24)=8.06$, $p=.001$ and a significant context by probe type interaction $F(6,48)=8.39$, $p<.001$. P3 latency was shortest for related words in the single word context condition and longest for nonwords. The longest latency P3s for real word probes were seen for unrelated words in the sentence context condition. P3 latency was significantly earlier for words related to topic than for unrelated words but was not significantly different for probe words related to the last word of the sentence. There was no significant difference in P3 latency for probe words related to the final word and those that were unrelated.

Relationship of P3 Latency and RT -

The latency of P3 was associated with reaction time. (In the Isolation Condition $r2= .338$, in the Sentence Context Condition $r2= .663$, and in the Single Word Context Condition $r2= .504$.) Figure 7 depicts this relationship.

It is important to note that RT was speeded only for related probes in the single word context condition relative to the speed with which these same stimuli were processed in isolation. RT for unrelated probe words in the sentence context condition was slowed. In

TABLE 13

MEAN P300 AMPLITUDES AND STANDARD DEVIATIONS BY CONDITION

Electrode Site		Sentence Context 1	2	3	Nonwords	Single Word Context 1	2	3	Nonwords
WORD PAIRS FIRST (N=5)									
P3	$\bar{X}$=	6.56	5.54	5.35	5.40	7.78	6.57	6.75	5.26
	s=	3.30	0.94	0.66	0.76	3.79	3.01	0.89	0.67
Cz	$\bar{X}$=	5.79	4.77	5.82	6.92	7.82	6.34	6.26	7.36
	s=	2.54	0.41	0.37	1.94	2.15	2.45	0.62	1.39
SENTENCES FIRST (N=5)									
P3	$\bar{X}$=	5.99	6.35	6.28	3.99	6.67	6.37	7.51	3.58
	s=	1.60	3.71	2.43	0.73	2.48	2.79	3.44	1.31
Cz	$\bar{X}$=	4.62	5.28	5.51	5.36	5.45	5.63	7.14	5.77
	s=	2.09	3.53	0.64	1.67	1.59	2.51	3.12	1.09
TOTAL SAMPLE (N=10)									
P3	$\bar{X}$=	6.28	5.99	5.81	4.70	7.16	6.46	7.13	4.42
	s=	2.46	2.72	1.75	1.02	2.97	2.70	2.40	1.32
Cz	$\bar{X}$=	5.21	5.06	5.66	6.14	6.50	5.95	6.70	6.57
	s=	2.28	2.52	0.52	1.89	2.14	2.36	2.17	1.45

TABLE 14

MEAN P300 LATENCIES AND STANDARD DEVIATIONS BY CONDITION AND BY PROBE TYPE

Electrode Site		Sentence Context 1	2	3	Nonwords	Single Word Context 1	2	3	Nonwords
WORD PAIRS FIRST (N=5)									
P3	X̄=	515.2	530.0	568.0	601.6	546.0	454.0	548.0	577.6
	s=	23.7	63.5	54.3	53.2	24.8	72.8	23.1	28.5
Cz	X̄=	505.6	526.0	568.0	590.4	536.0	444.0	540.0	574.4
	s=	22.9	66.1	54.3	46.4	20.7	86.3	12.1	32.7
SENTENCES FIRST (N=5)									
P3	X̄=	489.6	529.6	548.8	540.8	499.2	473.6	512.0	526.4
	s=	23.6	16.4	21.6	34.2	31.3	44.3	52.2	31.7
Cz	X̄=	472.0	524.8	539.2	532.8	486.4	459.2	499.2	520.0
	s=	33.5	24.4	29.2	40.2	41.0	47.9	54.4	20.4
TOTAL SAMPLE (N=10)									
P3	X̄=	502.4	529.8	558.4	571.2	520.0	464.9	523.6	552.0
	s=	26.1	40.6	40.2	53.0	36.4	55.5	50.0	39.2
Cz	X̄=	488.8	525.3	553.6	561.6	508.4	461.3	520.0	547.2
	s=	32.3	44.0	43.8	51.0	41.0	69.2	43.2	38.5

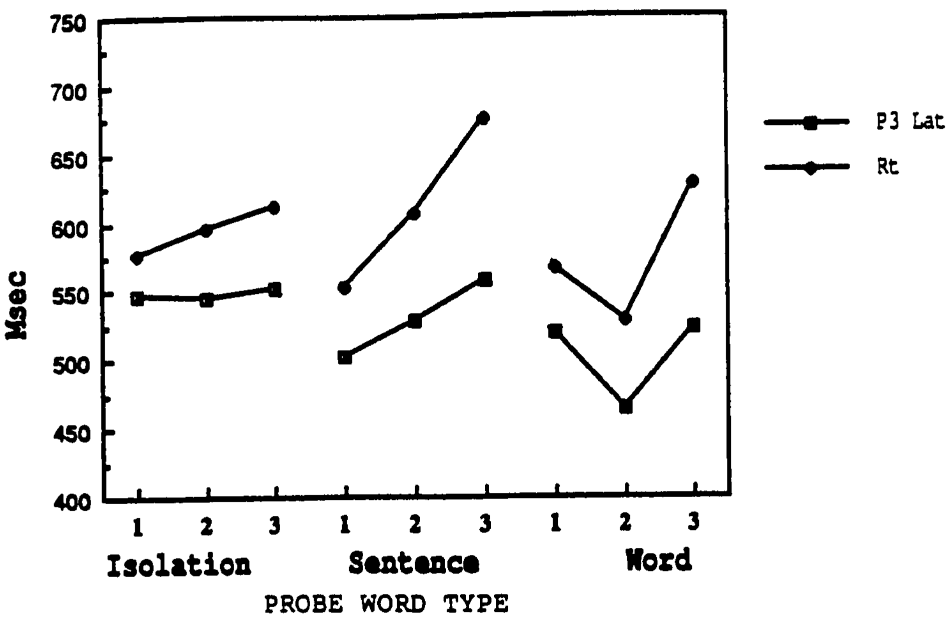


Figure 7. P3 latency and reaction time by context condition and probe word type.

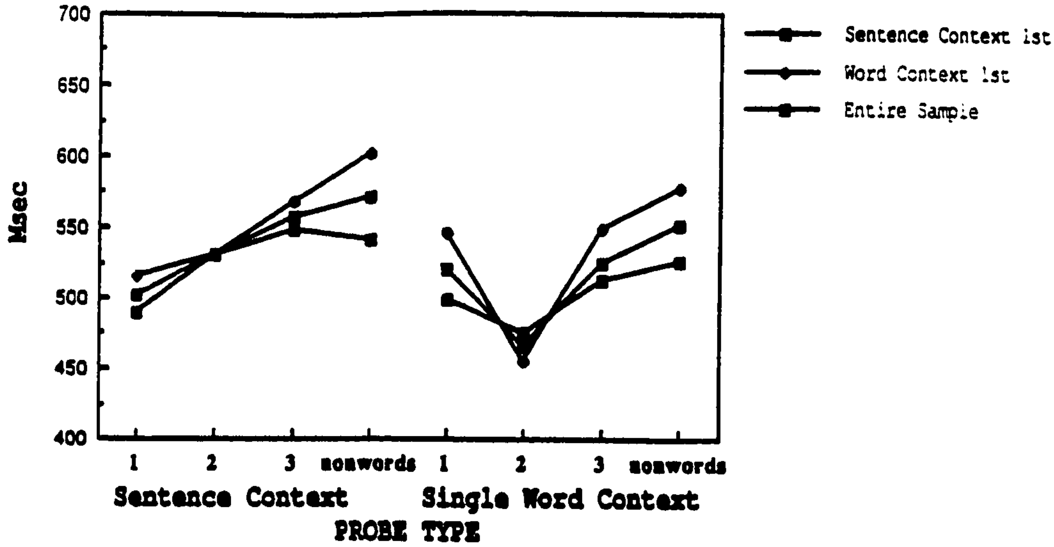


Figure 8. Mean P3 latencies for Sentence and Single Word Context Conditions in the two task order groups and the entire sample.

contrast, P3 latency was significantly reduced for probes related to topic in the sentence context condition as well as for related probes in the single word context condition. P3 latency was not significantly slowed for unrelated probe words in either context.

Figure 8 illustrates that there was no difference in the pattern of findings for the two task order groups.

DISCUSSION

The present studies through behavioral and electrophysiologic methods, have replicated the findings that both highly related sentence and single word contexts have priming effects on lexical processing and that unrelated contexts serve to slow processing (Fischler and Bloom, 1979; Stanovich and West, 1979; Kutas and Hillyard, 1980; Fischler et al., 1983). The goal of this project was to compare the level of activation of words in the lexicon as a result of the presentation of semantic (sentence topic) and lexical (single word/associative) contexts.

BEHAVIORAL EVIDENCE FOR PRIMING EFFECTS -

The behavioral study showed clear effects of lexical/associative context and semantic context on lexical processing.

The Strength of the Effects of Lexical vs. Semantic Context-

The present study supported the hypothesis that in connected speech, global topic context can have more of an impact on subsequent lexical processing than strong associative context. As shown in the sentence context condition, there was a significant difference between RTs for probe words that were related to the sentence topic ($\bar{X}$=606 msec) and those for probe words related only to the final word of the sentence ($\bar{X}$=642 msec).

Intralexical Spreading Activation as an Explanation for Sentence Context Effects -

It has been argued that sentence context effects are actually the result of spreading activation from individual words occurring in the sentences (Ratcliff, 1987). On the basis of the performance data from the present study this is an unlikely explanation. It is clear, through the comparison of the lexical decision RTs for the strong lexical associates in the single word context condition, with those obtained for the same lexical associates embedded in sentences, that associative priming can be modified by sentence context. Single word associative primes when presented without a larger linguistic context (as in the single word context condition) produced the strongest facilitation for the processing of probe words which immediately followed ($\bar{X}$ RT=555 msec). This robust lexical priming effect was attenuated in the sentence context condition. If lexical processing were facilitated only by associations among individual words and not by topics that we as listeners construct then the priming provided by a single lexical associate should not be influenced by topic context. To strengthen the argument a post hoc analysis was done in which RTs were compared for topic related probe words (targets) which followed sentences containing lexical associates to the probes ($\bar{X}$ RT =605.98 msec) with those that did not ($\bar{X}$ RT= 605.55 msec). (By definition topic related probes were never immediately preceded by a lexical associate.) There was no significant difference ($p=.724$). This supports the view that lexical associates embedded in sentences do not account entirely for the priming effects of sentence contexts.

The findings of the behavioral study concerning the role of lexical context in word processing in connected language are consistent with the results of Stanovich et al. (1985) and Simpson et al. (1989) in that they showed that sentence context effects do not derive only from 'intralexical' spreading activation. It extends their findings in that none of the stimuli used in the present study were semantically anomalous. The effect of lexical priming on subsequent word recognition in connected speech was studied in a more natural situation, in semantically and syntactically normal sentences. Lexical and semantic context were never in opposition. The goal of the present study was simply to determine the level of activation in the lexicon of semantically and associatively related probe words following the presentation of a normal sentence relative to unrelated words. This study supports the idea that words related to an established topic are activated more than words related to strong lexical associates in connected speech.

The Effects of Lexical/Associative Context -

It does appear that associative context can have some effect in connected speech when lexical associates occur adjacent to each other (Foss, 1982). In the present study the subjects responded with no significant difference in speed to the lexically associated probes when their primes were embedded as the last word in a sentence ($\bar{X}$=642 msec) and when these same stimuli were heard in isolation ($\bar{X}$=610 msec). However, responses for the lexically associated probe words (targets) in the sentence context condition were significantly quicker than responses to the unrelated words in the sentence condition ($\bar{X}$=703 msec) even though the lexical associates were unrelated to topic.

This brings up the question of the possible role of lexical context in connected speech. It is well documented that single word priming only has an effect when there is not a significant amount of time or more than one word between the prime and the target (Gough, Alford and Holly-Wilcox, 1981). As it is rare that 2 highly semantically related words occur next to one another in naturally occurring language, it is unlikely that lexical context plays much of a part in the processing of words in running speech. Even when two related words occur adjacent to one another in a larger semantic context, it appears that at least at the time interval of 1000 msec between prime and target used in the present study, the single word priming effect is not the same as when the word pair occurs in isolation. In a followup study it would be important to look at lexical priming utilizing time intervals between prime and target which are closer to those seen between words in natural speech. It is possible that lexical context may play more of a role in natural speech than that seen in this study because the time intervals between words are generally much shorter.

In sum, the findings of the behavioral study indicate that both lexical and semantic context play a role in the processing of words in connected speech, with semantic context having the stronger effect in connected speech. The effects of lexical context are attenuated in connected speech relative to what they are separate from a larger linguistic context.

PRIMING EFFECTS ON ERPS -

Significant changes in the P2, N360, and P3 components of the ERP within and between conditions were associated with semantic and lexical priming.

P2 -

The enhancement effect on the amplitude of the P2 component of the ERP across probe types was quite unexpected. The P2 was significantly enhanced for probes which were primed by strong lexical associates in both the single word and sentence context conditions. There was not a significant effect of topic context on P2 amplitude. The N1 and P2 components are believed by some to reflect the automatic analysis of the sensory features of a stimulus (Donald, 1979). Boddy (1981) was the first to relate the amplitude of these early components to semantic discrimination. In a semantic classification task, a category question (e.g., Is it a fish?) was followed 1500 msec later by a probe word that either belonged to the category or not. He asked subjects to make judgements about category membership. N1-P2 peak to peak amplitudes were significantly larger for positive than for negative instances of primed categories. Boddy interpreted his data as being consistent with the concept of automatic spreading activation. The results of the present work could also be interpreted this way as the P2 enhancement effect was seen with lexical context and was not seen with semantic context. Boddy's study and the present work support the possibility that P2 amplitude can be related to "the attainment of meaning of semantic stimuli".

Kutas and Hillyard (1989) in a word pairs study noted a slightly enhanced positivity "in the P220 region" for words primed by highly related lexical associates. They interpreted this as "probably reflecting the lack of subsequent negativity". Their observation is consistent with the findings of the present study but their interpretation can be brought into question. In the sentence context condition of the present study, the amplitude of P2 was larger for probes which were related to the final word of the sentence than for those related to topic. The negativity which followed P2 was also larger for probes related to the final word. This dissociation indicates that the enhancement of P2 seen here cannot simply be a reflection of the "lack of a subsequent negativity" and may be related to an early lexical priming effect.

N360 ('N4')-

The sentence context condition in the present study demonstrates a priming effect on N360 across a sentence boundary in auditorally presented material. N360 was largest in the sentence context condition for probes that were unrelated to either the topic of the sentence or to the final word of the sentence and was smallest for probes related to the topic. The observation of priming across a sentence boundary extends the previous finding of VanPetten and Kutas (1987). They investigated the activation of meaning in a visual lexical ambiguity study in which stimuli were sentences that ended in homographs followed by probes which were either a) related to the meaning of the homograph which was biased by the sentence, b) related to an unbiased meaning of the homograph, or c) completely unrelated. The purpose was to illuminate meanings which were activated in the lexicon following the presentation of a context. Their findings concerning differences in the amplitude of N400 indicated that at a stimulus onset asynchrony (SOA) of 700 msec, priming was only present for contextually appropriate probe words. (It is important to note that they defined priming as a reduction in N400 amplitude associated with related probes as compared to unrelated probes.) The results of the present study are consistent with their findings in that the greatest attenuation of N360 was seen for probes which were completely contextually appropriate (consistent with the meaning of the entire sentence). The present study demonstrates priming across a sentence boundary in the auditory modality and in addition, shows that primed information is not restricted to semantic features associated with a single word or location in the lexicon, but activation of meanings related to topic occurs as well.

The word pairs condition in the present study fails to confirm the findings of the Bentin et al. (1985) lexical decision semantic priming task in the auditory modality.
A slight attenuation of N360 for related probe words in the single word context condition was

observed, but the difference from unrelated probes was not significant.

The N360 results in this study must be interpreted carefully due to the relationship of P3 and N360. In this study P3 covaries with RT. As RTs are quicker in related probes words, and P3 latency is earlier, it could be argued that the P3 truncates the N360 complex thereby reducing its amplitude. Bentin et al (1985) addressed this issue directly in the single word priming, lexical decision task mentioned above. They reaveraged ERPs for nonwords and those for words which had not been preceded by a related word, including only those trials on which RTs were less than the mean RT (0.5 SD for a given subject) for the primed targets. Resultant ERP averages did not differ significantly for P300 latency or amplitude. However, a significant difference in the negative complex occurring between 250 and 600 msec remained between conditions. The one important difference between the Bentin et al. study and the present one was that they studied only the effects of associative priming on the ERP. The present study provides the first report on the effects of topic priming. Therefore generalizing from the Bentin et al. study to the present one may not be appropriate. Thus, their findings cannot be used to definitively rule out the P3 latency effect as being responsible for the change in amplitude of the negative complex occurring between 250 and 400 msecs.

For the present study, one argument against the interpretation that the N360 effect is really due to the shift in the latency of P3 is that if the P3 were indeed overlapping with the N360 then the amplitude of the P3 might be expected to be smaller than for the other probe types. The lack of a reduction in P3 amplitude in related compared with unrelated conditions could argue against this interpretation. On the other hand, it is generally known that frequently as P3 latency increases amplitude decreases. In the present study a significant trend in this direction was not seen. This suggests that there could be an underlying negativity for shorter latency P3s.

An attempt was made to separate P3 and N360 by topography but this was not possible because the differences in topography were minor.

Although some of the points raised can be used to argue against the interpretation of the N360 effect as being due to the shift in P3 latency, they cannot completely rule it out. In future studies of this kind it would be important to observe the changes in N360 amplitude under conditions where a decision about the probes was delayed sufficiently so that P3 latency would be extended well beyond the temporal window of interest for N360. Kutas and Hillyard (1989) have done this through the use of a letter monitoring task. For the present, although the N360 results are only suggestive, the RT and P3 latency data clearly support the presence of both semantic and lexical priming in connected speech.

P3 -

P3 amplitude was largest overlying the left parietal region for real words and largest over the midcentral region for nonwords. This difference in topography for real words and nonwords was largest in the isolation condition and was also seen in the single word context condition. It was not seen in the sentence context condition. The difference in P3 topography for real words and nonwords can be interpreted in light of the findings of Lovrich et al. (1988). In their study subjects participated in 3 tasks. One involved the selection of a single specified real word or nonword from a list, another involved a search for words within a list that fit a specified category and the third involved a simple detection of each stimulus without a discrimination being required. Of interest for the present study are their findings that P3 had a more posterior distribution for targets than nontargets and that the distribution extended furthest posteriorly when semantic processing was required. This is consistent with the more posterior maximum for meaningful words than nonwords in the present study.

P3 latency has been used for evaluating processing time involved in making a decision about a stimulus (McCarthy and Donchin, 1983). In the present study, processing time as indexed by P3 showed the same pattern as RT for lexical decision. The positive relationship between P3 latency and RT seen in the present study, has been widely reported in the literature (Ritter et al., 1972; McCarthy and Donchin, 1983; Rugg, 1983). Although, P3 varied with RT it is of interest that a greater facilitation effect was seen with related contexts for P3 latency than for RT, suggesting that ERP measures are more sensitive to the actual timing of the language related processes.

Both the present behavioral and electrophysiologic studies were geared towards shedding light on questions concerning the relationship and strengths of lexical and semantic context in connected speech. Before discussion of the implications of the present findings with respect to other issues in lexical processing (such as the locus of contextual effects and the interaction of different types of linguistic information) a more detailed description of models of word recognition is in order.

MODELS OF CONTEXT EFFECTS IN WORD RECOGNITION -

Most theorists agree that two major types of information are used in processing language. One of these is the sensory information (eg. acoustic-phonetic, orthographic) available from the stimulus and the other is information derived from previous context and linguistic knowledge (semantic, syntactic, and pragmatic). All models of word recognition attempt to describe and account for a common set of processes. Fraunfelder and Tyler (1987) have outlined these as including: Initial lexical contact, activation, selection, word recognition and lexical access. Initial lexical contact is the point at which some sensory representation of a word makes first contact with the lexical system. Defining the nature of this early representation is a major issue in the field. In the auditory system some have characterized it as a "temporally defined spectral template" (Klatt, 1980), others as a phoneme or syllable (Pisoni and Luce, 1987). In the auditory modality, Marslen-Wilson and Tyler (1980) proposed that since auditory language is temporally coded, information which occurs first contacts the lexicon first. Others argue that the most salient information in an auditory stimulus (eg. stressed syllables) makes initial contact without regard for temporal order (Grosjean and Gee, 1987). Many researchers argue that what have been called contact representations are quite different in the visual and auditory systems (Caramazza, 1988). All lexical items which match the initial input are activated. It stands to reason that the larger and more completely defined reason that the larger and more completely defined the segments which make first contact, the smaller the set of words which are activated. Activation refers to a change in the state of lexical items which results from a match with incoming sensory information. This change is a lowering of the threshold for word recognition. Most theories now are in agreement that the initial resting states of different items in the lexicon vary, depending on word frequency. Higher frequency words have lower thresholds. Selection is the process involved in locating the single appropriate lexical item. Different models describe this in very different ways. Forster (1976) views this as an ordered search through the lexicon which is based on the sensory characteristics of the stimulus and on word frequency. McClelland and Rumelhart (1986) present this as a process during which the activation levels of lexical items rise and fall through inhibition and facilitation. The word with an activation level exceeding a certain threshold is recognized. Marslen-Wilson (1987) has proposed that selection is made as the initially activated items decay in the face of disconfirming evidence. Word recognition is the end product of selection. Lexical access is complete at the point when stored lexical knowledge associated with a word (phonologic, semantic, syntactic, pragmatic information) is made available.

Critical to the discussion of context effects in lexical processing are the concepts of facilitation and inhibition, automatic and controlled processing, spreading activation and conscious expectancy and the idea that context might have its effect at a point in time which is either before or after lexical access.

Automatic and Attentional/Controlled Processes -

"Two-Process Theories" have to do with the allocation of attention in linguistic processing (Anderson and Bower, 1973; LaBerge and Samuels, 1974; Collins and Loftus, 1975; Posner and Snyder, 1975; Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). Access to long term memory is governed by two distinct processes, 1)automatic and 2)attentional/controlled (see Introduction). The mechanism responsible for automatic linguistic processing is generally accepted to be spreading activation (Collins and Loftus, 1975) of related items within the lexicon. Attentional/controlled processing is regarded by many as involving conscious expectancy. Interstimulus interval has been manipulated in studies to obtain information regarding the automaticity of a process. Neely (1977) supported "two-process theories" in a lexical decision study involving single word priming. He argued that the rise time for semantic activation is very rapid and facilitates lexical access (acts at the lexical level) and that the subject need not have a conscious awareness of the relationship between prime and target for this effect to be obtained. It was also demonstrated that only facilitation is present when the interstimulus interval (ISI) is very short (less than 150-200 msec) and that inhibition of unrelated words appears when there is more time between prime and target. It was suggested that a conscious expectancy develops at the longer ISI. The subject's attention is focussed on what is expected, therefore a response to the expected stimulus is facilitated while there is inhibition of unexpected stimuli.

Stanovich and West (1979) performed an analogous study. Employing pronunciation latency as a measure of semantic priming, they studied the time course of facilitative and inhibitory effects of sentence context. They varied the ISI between the sentence context and the final word of the sentence. They found that relative to a minimal context condition there was only facilitation for related words present at an ISI of 150 msec and that inhibition of unrelated meanings was not in evidence until 750 msec after the completion of the sentence. This result is consistent with the findings in single word priming studies.

Linguistic Processing: Pre and Post Lexical Access -

Prelexical processes have been defined as "the decoding processes that result in identification (recognition) of a signal as a particular word". Postlexical processes occur after recognition is complete and "involve selection, elaboration and integration of lexical information for the purpose of understanding an utterance" (Seidenberg et al., 1984). All theories agree that sentence contexts have post lexical effects. At issue in the literature is whether sentence/topic contexts can have prelexical effects as well. For some investigators, automatic and attentional processes are taken to be isomorphic with prelexical language processes and post lexical language processes, respectively. (Seidenberg et al., 1984). Prelexical processing is seen as automatic and contextual effects which act prelexically can only be facilitative. Post lexical processing is seen as coming from a limited capacity attentional mechanism and involving active decision making and the development of expectancies. In this view, post lexical contextual effects have facilitory and inhibitory influences. However, as will be discussed in the descriptions of the linguistic processing models presented below, some investigators have proposed that both facilitative and inhibitory sentence context effects have some impact prelexically, before word recognition is complete. In this view, the presence of inhibition effects does not necessarily imply conscious expectancy. Prelexical sentence/topic context effects, do not involve expectancies (Marslen-Wilson and Tyler, 1980).

Prototypic Models of Word Recognition -

There are numerous models of the language processing system, but these generally fall into two categories - autonomous and interactive. The strictest autonomous models propose that language processing is carried out through a series of autonomous processing modules and that there can be no communication between levels of the system. In interactive models information from different levels of the system can interact. Lexical recognition is determined by sensory information and context. In reviewing models of language processing it becomes clear that a true categorical distinction cannot be made between autonomous and interactive models. Rather the models fall on a continuum. The major models of lexical processing and their implications for the interpretation of context effects are discussed below. Each model chosen for discussion is prototypic of a class of language processing models.

a) The Autonomous Search Model -

Fodor's (1983) model is probably the most well known autonomous model. He describes the entire language processing system as a single module whose operations cannot be influenced by world knowledge which is dealt with in a separate cognitive module. As will be seen below other autonomous models propose more circumscribed modules which provide more constraints on the processing of linguistic material and therefore can be tested more easily. Forster's (1979) autonomous search model presents the language system as being comprised of a series of completely autonomous processing modules. Processing is serial and there can be no interaction between different modules. All information is processed in a bottom-up or data driven fashion. The three linguistic modules in Forster's system are 1) the lexical processor 2)the syntactic processor and 3) the message processor. First sensory information enters the lexical processor where a search proceeds to locate the lexical item. This is done entirely on the basis of the acoustic and phonetic or orthographic characteristics of the stimulus. Word frequency is coded in the lexicon so that the search proceeds from higher frequency words to low frequency words. Once the lexical item is located word recognition is complete. The result of the lexical search is then submitted to the syntactic processor which incorporates the word into a syntactic structure and finally the output of the syntactic processor is sent on to the message processor where a concept of the meaning of an utterance is developed. Although there cannot be any interaction between information in the independant modules, information within a particular level can interact. In this model, single word/associative context can facilitate lexical processing. The autonomy assumption is preserved, as this is an intralexical effect. The concept of associative priming is therefore easily accomodated by this model and thought to account for facilitation effects seen with sentence contexts. Facilitation of word recognition by syntactic or higher level semantic and interpretive information is forbidden by this model. These types of context can only play a part when language processing is made more difficult or is slowed down (as in the case of ambiguity or a 'degraded' signal) when lexical selection is already complete. They have no role in facilitating lexical access in everyday conversations or in reading and do not act prelexically (Forster 1981). Lexical access is 'modular' and autonomous and unaffected by sentence level expectancies. Experienced language users have attained rapid, automatic lexical access and do not need context to speed recognition (Forster, 1979). When higher order context does have an effect (as when it is involved in choosing the contextually appropriate sense of an ambiguous word) it is felt that this is a slower acting effect which takes place in the post lexical processing modules and acts to inhibit information inconsistent with the global context.

b) The Logogen Model -

Morton's (1982) logogen model is one of the strongest interaction models. This theory explains lexical recognition as taking place through the activation of logogens, which can be defined as passive sensing devices which make up the lexicon. Each word in a person's vocabulary and all associated information is contained in a single logogen. This information includes not only a semantic representation but also phonetic and orthographic features as well as information about syntactic function. Logogens have a certain preset threshold for activation which is determined by word frequency. Thresholds are lowest for the most frequent words. Activation of a logogen increases when any sensory or contextual information related to a particular lexical item is received. For example, after a word is heard or read information associated with that word remains activated and reduces the recognition threshold for that word and associated words, acting prelexically. When a certain level of activation is attained and the threshold is exceeded, the word is recognized. The proposition that all information about a word is represented in a logogen means that all information from all sources can interact directly during the process of word recognition, including word frequency. Both topic and associative context have an effect at a very early point and can lower the threshold for activation before an input is received. Grosjean (1980) gives a similar account but in his theory the mechanism is not a lowering of threshold but rather the initial group of lexical items which is contacted is limited to words which are consistent with the semantic context. Becker's (1980) Verification Model states that semantic context acts to generate an expected set of words which is scanned for consistency with the input. The entire semantic priming effect in his model is related to expectancy and attentional processing strategies.

c)Cohort Theory -

Marslen-Wilson's (Marslen-Wilson and Tyler, 1980) Cohort Theory is another interactive theory of word recognition. It is the most prominent of a group of similar models which were built on the data obtained through studies in the auditory modality. It is different from the Logogen model in that it posits two separate stages involved in word recognition. The first is autonomous and the second highly interactive. The initial acoustic and phonetic information available in an auditorally presented word activates all words that begin with the same sound. This is a concept which has been incorporated into many models. In this model there is no specification of the characteristics of the acoustic information that initially contacts the lexicon. Presumably, it is some segment of the first part of the word. This first stage is a bottom up, data driven process. No higher level contextual information can interact at this level. The term "cohort" is used as a label for the group of words that is activated in the autonomous stage. Higher order semantic, syntactic and interpretive contexts, have their effect after the initial cohort is identified, but unlike Forster's model, before word recognition is complete, by inhibiting and deactivating members of the cohort which are inconsistent with the rest of the input. This is an automatic inhibition which does not require conscious expectancy. Further acoustic/phonetic information available after the initial cohort selection also limits the cohort. When a single member is selected from the cohort, word recognition is complete. During selection, the sensory and contextual constraints on the identity of a word are integrated at a time when either source of information alone would be inadequate. The evidence cited to support this position is from gating and shadowing paradigms. Gating paradigms involve the auditory presentation of brief portions of a word beginning with the initial phoneme. Auditorally presented words in natural context are recognized and responded to accurately by adults when less than half the word has been heard. At that point there is not enough acoustic information available for that word to have been processed in isolation (Marslen-Wilson and Tyler, 1980a; Grosjean, 1980). This facilitation effect decreases systematically as the contraints provided by the context decrease (Grosjean, 1980). In this model, just as the sensory input specifies a cohort of candidates so does the context. It is the overlap between the two which specifies the word. The brief autonomous period is important because it is the period during which a variety of properties of all of the words in the cohort are first available, through spreading activation, to be evaluated in light of the properties of the semantic context. In this model sentence context is not believed to have its effect through spreading activation. To reiterate, although the process of word recognition begins with a brief stage of data-driven processing, it is susceptible to the influence of higher order context at a point in time before word recognition is complete. Therefore any contextual information available may be involved in a prelexical recognition/selection process. This prelexical selection process does not involve a preselection of word candidates. Rather, there is a selection among candidates already activated by the sensory input.

d) Interactive Activation Theory -

Elman and McClelland's (1986) interactive activation theory proposes that linguistic processing involves processing nodes. Nodes represent orthographic or acoustic features, whole phonemes, or entire words. Each node can be activated by incoming information which is coded in that node. Each has a preset recognition threshold. Activation rises towards threshold when over time incoming information continues to be consistent with information coded in that node. If there is no consitency then activation decays and the node begins to return to its resting state. The nodes are part of a network and are highly interconnected thus a node that has reached threshold can influence the state of other connected nodes. This influence can be excitatory or inhibitory. Elman and McClelland (1986) are quite specific about the location of excitatory and inhibitory connections in the system. Only inhibitory connections are present within a level (e.g., the phonemic level, the word level). Excitatory connections are present between levels. All connections are bidirectional. The feedback loops within this system make it possible for both internally and externally generated representations to be interactively involved in word recognition and the resolution of meaning. This is one of a class of models that takes the organization of the brain as its basis.

Significance of the Current Findings Concerning Locus of Contextual Effects -

All models agree that the presentation of a linguistic context can alter the state in memory of related words. The controversies in the field relate to two major issues:

1) What types of context influence lexical processing and what are the relative strengths of their effects? Specifically, what is the contribution of associative/single word priming in connected speech? Can the facilitation of lexical processing seen with some sentences be accounted for by associative/single word priming effects?

2) When do different types of context have their effects? In lexical processing, is selection a pre or post lexical process? Can lexical context influence sensory processing? Can semantic context affect the decoding of a stimulus or only aid in post recognition judgements about the stimulus ?

Questions concerning the relative strengths of the effects of different types of context on lexical processing in connected speech were directly addressed by this project and have been discussed. Although not the original intent, the findings of the present investigation can be evaluated with regard to the locus of the contextual effects observed because ERPs provide information concerning real time, on-line cortical processing.

The Timing of Lexical and Semantic Context Effects -

Behavioral Study -

It is difficult to speculate about the locus (pre or post lexical access) of the sentence topic context effects based on the behavioral findings in the present studies.

The behavioral study on its own is of limited use in determining the locus of the semantic and lexical contextual effects. In the behavioral literature facilitatory effects in the absence of inhibitory effects are generally interpreted to reflect automatic prelexical processing.

In the single word context condition there was a strong reduction of RT for related words. The same facilitation was evident in P3 latency. In and of itself, this does not aid in discriminating between models of lexical processing. All models agree that this type of context can have its effect prelexically.

In the sentence context condition, the RT for unrelated probe words was generally prolonged. The group mean RTs for the related probes in the sentence context conditions showed no facilitation as compared to when these same words were presented in isolation. Interestingly, the latter finding was not the same in all individual subjects. In fact 11 of the 26 subjects showed facilitation for probe words related to sentence topic. This individual variation could indicate that different strategies are used by individual subjects. It may be that topic context does act before word recognition is complete but because it can also be involved in the complicated off-line process of making decisions about the linguistic input, the early automatic effect may be obscured by later processing. A subject who was generally slow and careful in responding may have used a strategy which emphasized the post lexical effects of semantic context. While subjects who were quick to respond emphasized automatic processing. A facilitation dominant pattern was seen in the P3 data. P3 latency was shortened (facilitated) for words related to sentence topic and for related words in the single word context condition without at the same time being lengthened (inhibited) for unrelated probe words. P3 latency may turn out to be a sensitive indicator of the locus of the global context effect.

In order to make judgements concerning the facilitory or inhibitory effects of context, RT and P3 latency for probe words in context the present study directly compared with RT and P3 for the same words in isolation. The interpretation of faster or slower processing as indicating facilitation or inhibition of word recognition must be done with a critical eye. In specifying facilitory and inhibitory contextual effects in any behavioral study the type of comparison condition used is of critical importance. Comparisons are most commonly made 1)between related and unrelated probes within a single word or sentence context condition or 2)between probes when they occur in a biasing context and when they occur in isolation or in a separate neutral context condition. The problem with comparisons of the first type is that it is not possible to get information about the inhibition of processing which may derive from an unrelated context. The comparison condition (Isolated Words Condition) used in the present study is not optimal either. In a repeated measures design where the same subject is observed under all conditions, facilitation of word processing can be due in part to repetition effects. It is difficult to determine the relative contributions of semantic or lexical priming and repetition to facilitation. It is however possible to observe inhibition. Another reason that the isolated word condition in the present study may not be optimal is that even though the stimuli were randomly ordered and there were three seconds between words, most of the word probes followed nonwords or words to which they were not related. Inhibitory priming effects may have been present in the isolated word condition. For future work, a neutral context in which each word in the isolation condition was preceded by a sound or a word such as 'the' would provide a cleaner contrast. The interpretation of facilitory effects in the present study clearly must be guarded. However, the contrast condition used provided important information concerning differences in the patterns of speeded and slowed processing relative to the isolation condition as evidenced by RT and P3 latency.

Although it is not clear whether global topic context had an effect prelexically and the length of the ISI used in the present study allowed for the development of conscious expectations, it is unlikely that the topic context effects seen here were due to expectancy. In CLOZE probability paradigms, where a highly constraining sentence is used it is quite possible to develop an expectation about what the last word will be. However, here, specific expectations about the identity of the probes related to topic in the sentence context condition would almost never be met and processing would be slowed. This is not in fact what was seen.

The P2 Enhancement Effect -

Of particular interest for the discussion of the timing of context effects, is the finding in the present study that the amplitude of P2 was enhanced in conditions where a probe had been primed by a lexical associate, even when the associates were embedded in a larger linguistic context (as in the sentence context condition). This is not only consistent with Boddy's (1981) idea that P2 amplitude can reflect priming and discrimination of lexical material but is also consistent with the notion that associative/lexical context might influence word recognition before it is complete (prelexically). The present findings indicate that there may be an interaction of lexical context and sensory information. Ganong (1980) reported a related behavioral study of lexical context effects on sensory processing. He presented his subjects with ambiguous phonemes which fell along a voice onset time continuum. They were presented in the context of a word ending. If the phoneme was perceived in one way the subject would hear a real word (e.g., kiss). If it was perceived as the other phoneme on the continuum the subject would hear a nonword (e.g., giss). In a lexical decision task subjects responded to significantly more stimuli as words than nonwords. He interpreted this to indicate that lexical information influences phonemic processing.

The P2 enhancement effect seen in the present study may through future investigations, clarify the issues regarding modular and interactive models of word recognition. Although not significant, P2 amplitude for probe words related to topic context also showed a slight enhancement. If in future studies it were shown that P2 for probe words related to topic was significantly enhanced this would provide powerful evidence for interactive models. If instead it were shown that the P2 was enhanced only by strong lexical context then this would support a modular view in which, at least for a short period of time, lexical search being done on the basis of sensory features could be enhanced only by lexical context.

Directions for Future Research -

These studies have raised a number of questions for future investigation.

1) Differences in the Auditory and Visual System -

Some of the models described above have been built primarily on data obtained in the visual modality. The Cohort Model and the Interactive Activation Theory are among the few based on auditory data. A general application of these models to linguistic processing in all modalities assumes that auditory and visual pattern recognition systems converge on the same lexical system (Morton, 1969). Lexical processing of auditorally presented language may be different from visually mediated language as spoken words must be experienced sequentially. An auditory word might be recognized and might be able to influence the processing of susequent information before it is complete. It has been suggested (Forster,1981) that lexical recognition in fluent speech may be more strongly influenced by higher level context than auditory words occuring in isolation or visually presented words because in connected speech the stimulus is degraded due to variables like "imprecise articulation and coarticulation effects." This might mean that context could play a different role in linguistic processing in the two modalities. This remains an empirical question for future investigation.

2) In a followup ERP study, the problem of the P3 obscuring the N360 might be dealt with through the use of a paradigm which moves the behavioral response and the P3 out well beyond the latency range in which this negative complex is seen. Kutas and Hillyard (1989) have recently elicited an N4 with the typical topography in a word pair priming paradigm, eliminating the P3 component, by delaying a decision about the probe through the use of a letter monitoring task. VanPetten and Kutas (1987) used the same paradigm with sentence contexts. After the presentation of the probe (1500 msec) they asked the subject to report if a particular letter had been part of the probe. This was done simply to ensure that the subject attended to the probe. It would be important to carefully consider the level of processing engaged by such a task in interpreting data. The assumption here is that if a subject attends to a stimulus that it will be processed semantically rather than just visually. This assumption is supported by the results of these same N400 studies. However, Deacon et al. (in press) found that in word lists, when subjects were asked to make a size discrimination rather than a discrimination based on semantic category, N400 was in fact not elicited. It may be true that subjects processed target words quite differently in the Deacon et al. study and in the VanPetten and Kutas study. Subjects may have found it easier to perform the letter monitoring task if they remembered the probe words by processing them semantically. In the Deacon et al. study it is likely that visual discrimination performance could be optimized without processing the stimuli for meaning.

3) It would be important to replicate what may be semantic context effects on the processes underlying the early P2 component of the ERP and then to extend the investigation to study the other conditions under which these effects are seen.

Through the present investigation, it is clearly seen that electrophysiologic methods can provide important information concerning linguistic processing that could not be gained through the use of the traditional behavioral measures alone. Future investigation utilizing these methods in conjunction with strong behavioral paradigms will provide important on-line information about the timing of linguistic processes.

APPENDIX A
STIMULI

TARGETS RELATED TO THE SENTENCE TOPIC:	Probability of Association
MOST SHARK ATTACKS OCCUR VERY CLOSE TO SHORE. DANGER	.24
THE WHOLE TOWN CAME TO HEAR THE MAYOR SPEAK. POLITICS	.19
THE DISPUTE WAS SETTLED BY A THIRD PARTY. MEDIATE	.26
MOST CATS SEE VERY WELL AT NIGHT. VISION	.31
THE WEALTHY CHILD WENT TO A PRIVATE SCHOOL. PRIVLEDGE	.30
FATHER CARVED THE TURKEY WITH A KNIFE. THANKSGIVING	.70
THEY LEFT THE DIRTY DISHES IN THE SINK. LAZY	.10
THE ACADEMIC YEAR BEGAN IN THE FALL. SCHOOL	.56
THE PAINT TURNED OUT TO BE THE WRONG COLOR. MISTAKE	.33
THEY SAT TOGETHER WITHOUT SPEAKING A SINGLE WORD. SILENCE	.43
BOB PROPOSED BUT SHE TURNED HIM DOWN. REJECTION	.25
JEAN WAS GLAD THE AFFAIR WAS OVER. RELIEF	.51
THE GROCER CHECKED HIS STOCK BEFORE GOING HOME. INVENTORY	.45
HIS LEAVING HOME AMAZED ALL HIS FRIENDS. INDEPENDANT	.32
RAY FELL DOWN AND SKINNED HIS KNEES. HURT	.13
THE SOLDIER COMPLAINED THAT HIS PORTION WAS TOO SMALL. HUNGRY	.55
THE PARENTS PLEADED WITH THEIR DAUGHTER TO	.29

COME HOME. RUNAWAY

BILL PLAYED HIS STEREO MUCH TOO LOUDLY. INCONSIDERATE .16

OUR GUESTS SHOULD BE ARRIVING SOON. PARTY .18

TARGETS RELATED TO THE FINAL WORD OF THE SENTENCE ONLY:

The game was called when it started to RAIN. WATER .21

All the guests had a very good TIME. CLOCK .26

To keep the dogs out of the yard he put up a FENCE. PICKET .25

The kids fed the ducks some stale BREAD. BUTTER .63

He liked lemon and sugar in his TEA. COFFEE .41

The children held out their hands and formed a CIRCLE. SQUARE .24

Phil put some drops in his EYES. SEE .23

He shouted at the top of his LUNGS. BREATH .47

I added my name to the LIST. SHOPPING .25

When the two of them met one of them held out a HAND. FINGERS .33

The bill was due at the end of the MONTH. YEAR .47

At night the old woman locked the DOOR. OPEN .45

The governor vetoed the BILL. PAY .43

None of the books made any SENSE. SMELL .18

At first the woman refused but she changed .37

her MIND. BRAIN

He was afraid to work the night SHIFT. .16
GEARS

Jan boiled the eggs in WATER. .26
DRINK

The girl knew a lot for her AGE. .66
OLD

Abbey brushed her teeth after every MEAL. .42
EAT

TARGETS UNRELATED TO TOPIC OR FINAL WORD:

He scraped the cold food from his plate.
BOAT

When the power went out the house became dark.
PRIDE

He loosened the tie around his neck.
CEILING

His job was to keep the sidewalk clean.
SOFTLY

He mailed the letter without a stamp.
CLIMB

The crime rate has gone up this year.
BOWL

We sprayed the yard to keep away the bugs.
BORING

Water and sunshine help plants grow.
REVENGE

She went to the salon to color her hair.
TRUCK

Sharon dried the bowls with a towel.
DEMOLISH

To pay for the car Al simply wrote a check.
STATISTICS

Dillinger once robbed that bank.
CONFUSING

The squirrel stored some nuts in the tree.
FRIENDLY

Dick wrote a chapter in the book.
SNEEZE

The piano was out of tune.
BURN

The winter was very harsh this year.
PEROGATIVE

The old milk tasted very sour.
FAR

Jean hurriedly shoved her way through the crowd.
MORTGAGE

The better students thought the test was too easy.
POND

SENTENCES WITH NONWORD TARGETS:

Captain Sheir wanted to stay with the sinking ship.
DAFA

Three people were killed in a major highway accident.
TRO

He wondered if the storm had done much damage.
POBBIT

Joan fed her baby some warm milk.
FOON

John swept the floor with a broom.
WAGGUL

The pigs wallowed in their mud.
SNEEB

Karen awoke after a bad dream.
FUG

The pizza was too hot to eat.
MEDAPAT

They raised pigs on their farm.
LAWDA

The child was born with a rare disease.
BOBE

The cows moved from the sun into the shade.
SOWK

Tim threw a rock and broke a window.
VIDEEN

The ship disappeared into the thick fog.
DAIP

I could not remember his name.
RAS

The boat passed easily under the bridge.
PARNU

The gambler had a streak of bad luck.
CLON

Vic asked her to repeat what she had said.
PAG

Fred realized the old house was up for sale.
LERG

The gas station is about two miles down the road.
DRIN

The lecture should last about one hour.
EAN

His boss refused to give him a raise.
PILLAD

The old house will be torn down.
FORP

It is hard to sdmit when one is wrong.
BUNNA

Her job was easy most of the time.
DRID

When you go to bed turn off the lights.
FARP

The dough was put in the hot oven.
DIRL

Her shoes were the wrong size.
BOKE

The hungry bear found some stale bread.
BEP

The baby cried and upset her mother.
WOB

He bought them in the candy store.
LAVY

The lawyer feared that his client was guilty.
SKOOF

If the crowd quiets down the band will play.
CAWTAY

George could not believe that his son stole a car.
COWP

He crept into the room without a sound.
SEEF

At last the time for action has come.
FREKKY

The children went outside to play.
FINDA

The movie was so jammed they couldn't find a seat.
LEKKA

The exit was marked by a large sign.
FAWDAP

He lay down and went to sleep.
DEBIK

John felt sorry but it was not his fault.
MIPTATE

The teacher wrote the problem on the board.
CIRPAB

Pam did not have any clothes to wear.
PAFE

Shuffle the cards before you deal.
YEED

Success is often just a matter of hard work.
SIBET

George must keep his pet on a leash.
LEPPEN

Yesterday they canoed down the river.
SIM

Jan tried to squeeze in but there was no room.
MORDAP

The movers put the sofa on the bear floor.
BARPIN

She tied-up her hair with a yellow ribbon.
SIDDIP

Don't believe anything you hear.
REDDIPIN

He hung her coat in the closet.
UDD

After dinner they washed the dishes.
OBAP

The winter was very harsh this year.
SWEEB

The boys helped Jane wax her car.
REDAP

We sometimes forget that golf is just a game.
HEP

Don't touch the wet paint.
SHOON

Even for an amateur he was pretty good.
MIPA

APPENDIX B

INDIVIDUAL SUBJECT MEAN REACTION TIMES AND STANDARD DEVIATIONS BY CONDITION

Sentence Context			Single Word Context			Isolation		
1	2	3	1	2	3	1	2	3
WORD PAIRS FIRST (N=13)								
007								
671	627	672	651	653	660	621	636	657
120.8	81.6	122.0	68.4	94.6	69.1	58.0	97.5	124.0
008								
618	663	656	629	582	656	602	585	597
49.5	96.8	76.2	58.5	61.6	72.8	78.5	81.7	121.3
010								
564	552	605	530	492	610	504	514	560
104.4	74.7	95.1	66.0	65.1	152.2	64.5	68.4	105.5
011								
706	730	717	588	560	643	574	608	608
128.0	135.3	114.8	55.1	31.6	80.0	54.6	83.9	107.1
012								
556	592	646	573	537	674	596	628	613
62.8	102.9	96.6	86.3	83.4	120.9	83.8	84.2	59.7
013								
643	632	721	634	606	690	576	594	634
67.0	71.6	73.7	79.6	82.3	109.2	55.5	103.8	82.8
014								
678	817	867	684	653	705	750	656	703
100.6	212.4	248.7	151.0	136.0	127.7	175.1	87.9	99.9
016								
690	737	800	711	692	708	653	646	633
174.5	115.1	121.4	114.0	114.7	97.9	87.8	78.6	103.8
018								
602	659	688	623	559	657	621	619	645
70.9	108.4	70.4	54.6	77.3	69.7	73.5	43.4	101.9
020								
651	702	755	630	609	792	669	687	695
69.1	100.8	108.2	63.2	80.6	150.1	91.5	91.2	133.0

Sentence Context			Single Word Context			Isolation		
1	2	3	1	2	3	1	2	3
021								
626	638	710	686	611	694	631	673	670
143.5	92.4	116.7	95.5	163.3	75.5	65.8	72.2	118.3
022								
525	658	681	539	467	607	522	542	548
88.3	280.7	133.1	89.3	49.4	94.4	47.9	70.0	87.2
024								
530	557	614	541	499	611	616	570	648
32.3	74.3	111.4	34.4	68.0	105.0	59.7	62.5	105.7
X=								
619.9	658.6	702.4	616.9	567.5	669.6	610.4	612.2	631.6
s=								
60.8	74.4	73.3	59.3	66.1	50.6	62.7	50.5	46.4

SENTENCES FIRST (N=13)

001								
608	608	682	592	543	635	587	599	655
66.8	80.3	116.7	59.1	124.3	62.5	74.2	55.5	94.9
002								
572	528	629	519	530	540	584	560	601
73.3	62.3	111.7	59.7	70.8	75.5	67.6	50.0	80.2
003								
770	808	833	684	643	737	784	799	708
180.7	298.5	115.9	97.2	177.5	127.5	191.9	167.9	104.9
004								
602	707	713	580	545	644	626	703	579
75.7	151.1	100.8	73.2	76.2	93.0	52.2	59.7	46.5
005								
725	786	825	703	617	721	617	795	744
76.1	102.6	136.2	103.7	68.8	86.3	55.2	195.9	116.8
006								
653	672	709	596	540	613	625	605	746
86.5	109.4	97.1	86.1	65.9	132.1	80.6	56.1	125.6
009								
584	583	605	582	565	638	623	555	577
64.4	115.3	65.9	72.8	86.1	107.7	88.9	72.7	181.3

Sentence Context 1	2	3	Single Word Context 1	2	3	Isolation 1	2	3
015								
586	581	637	563	513	619	527	535	560
81.0	72.1	107.0	33.2	55.1	64.3	69.2	60.3	87.1
017								
543	632	755	581	596	637	549	645	668
48.7	110.7	158.4	63.5	109.8	115.9	60.0	154.9	136.4
019								
521	575	597	512	495	556	519	558	553
62.7	107.9	67.4	69.2	72.3	94.5	37.9	111.0	101.2
023								
570	557	645	462	468	528	534	531	543
75.8	75.7	113.1	49.7	67.2	83.4	77.3	69.0	46.0
025								
443	533	710	532	500	621	566	585	592
112.7	75.9	155.2	70.8	86.3	117.0	52.6	91.2	98.0
026								
520	568	604	548	488	575	544	541	563
50.2	91.2	60.4	72.8	63.8	72.4	64.4	82.5	87.3
X=								
592.2	625.9	703.4	573.3	541.7	620.2	591.3	608.5	622.2
s=								
86.3	91.6	79.8	65.7	52.1	62.0	69.9	90.7	73.2

ENTIRE SAMPLE (N=26)

X=								
606.1	642.2	702.9	595.1	554.6	644.9	600.8	610.4	626.9
s=								
74.5	83.4	75.1	65.2	59.8	60.9	65.8	71.5	60.2

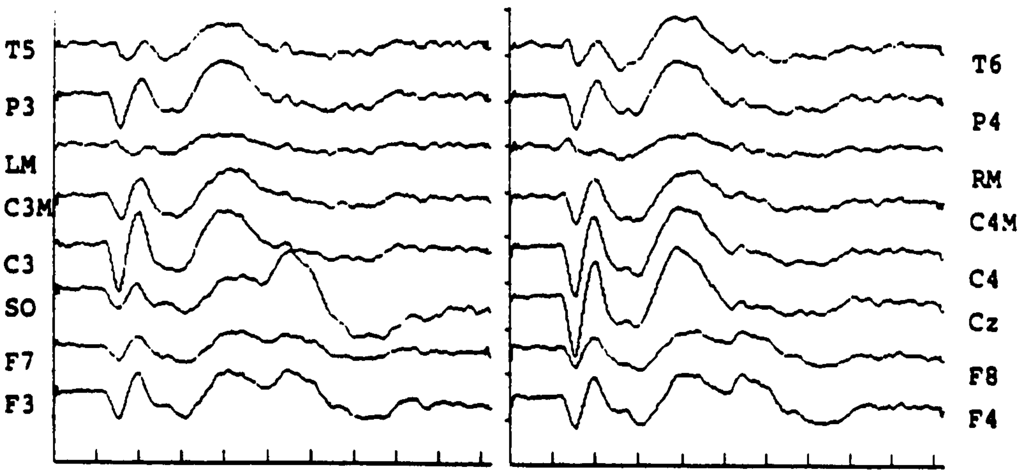
Key - Sentence Context
- 1 - related to topic
- 2 - related to final word of sentence
- 3 - unrelated to sentence or final word

Single Word Context
- 1 - unrelated
- 2 - related
- 3 - unrelated

APPENDIX C

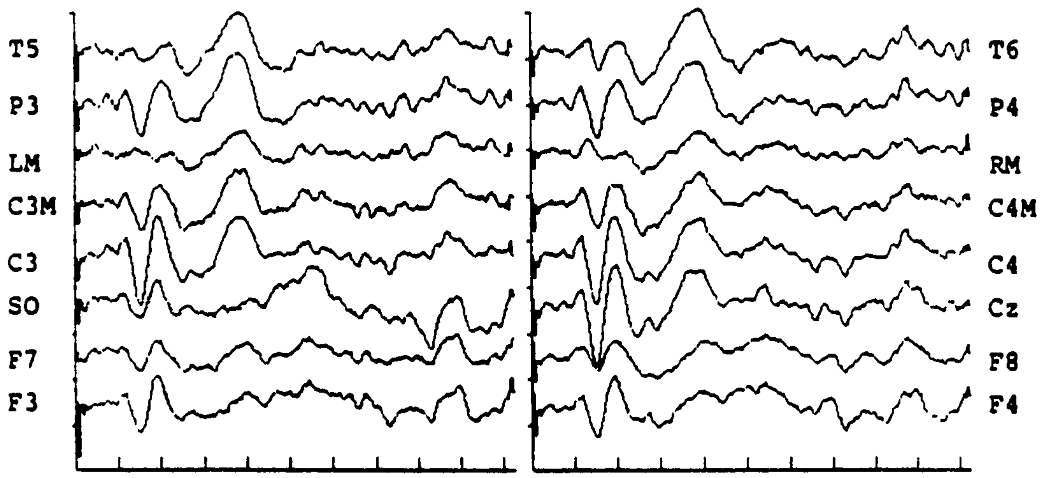
ms/div 200.000 uV/div 5.00

ISOLATED WORDS CONDITION-NONWORDS



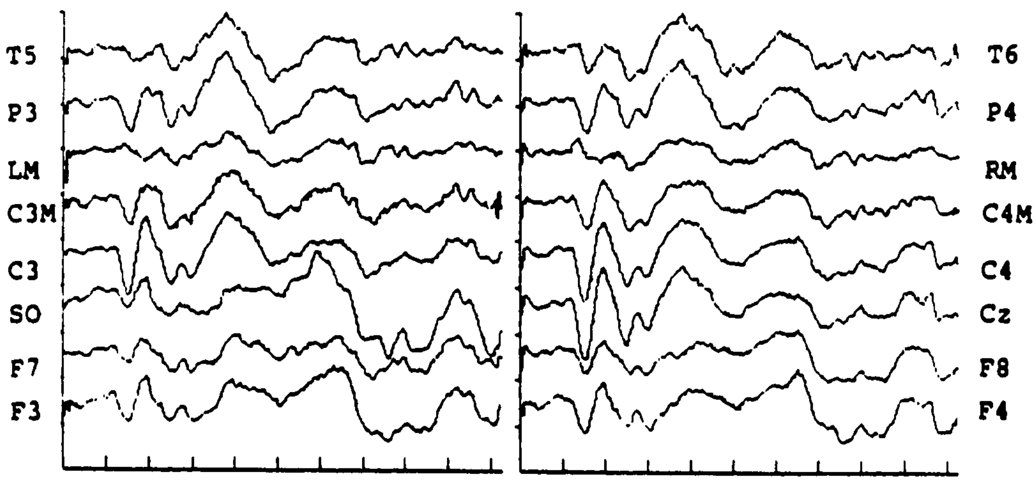
ms/div 200.000   uV/div 5.00

ISOLATED WORDS CONDITION-PROBE WORDS 1



ms/div uV/div
200.000 5.00

ISOLATED WORDS CONDITION-PROBE WORDS 2



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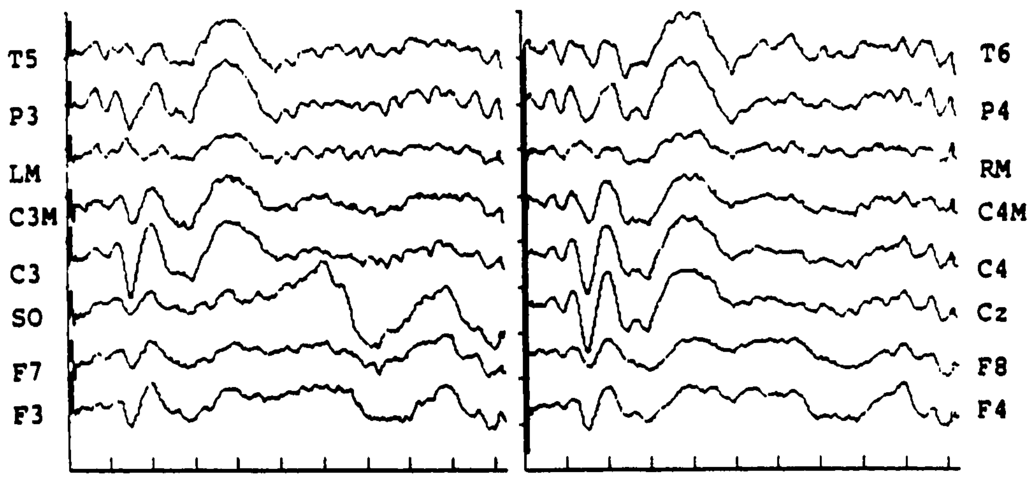
ISOLATED WORDS CONDITION-PROBE WORDS 3



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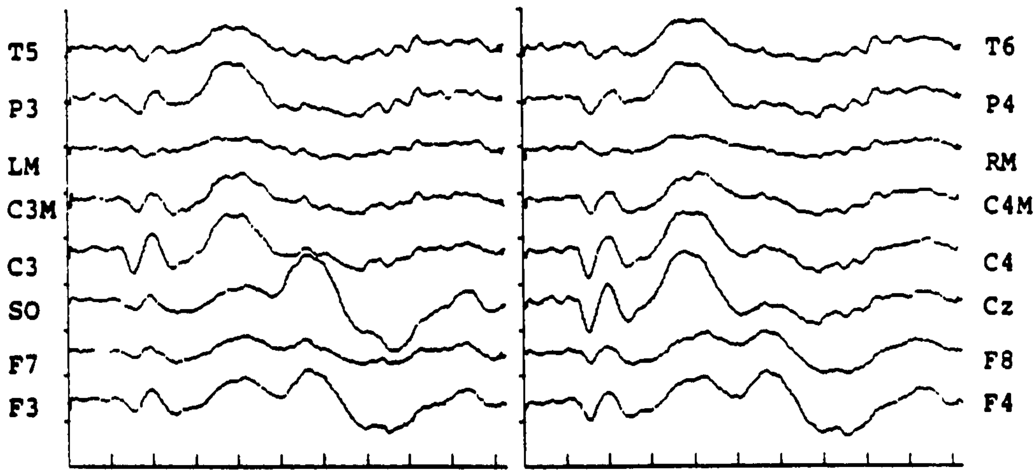
SENTENCE CONTEXT CONDITION-NONWORDS



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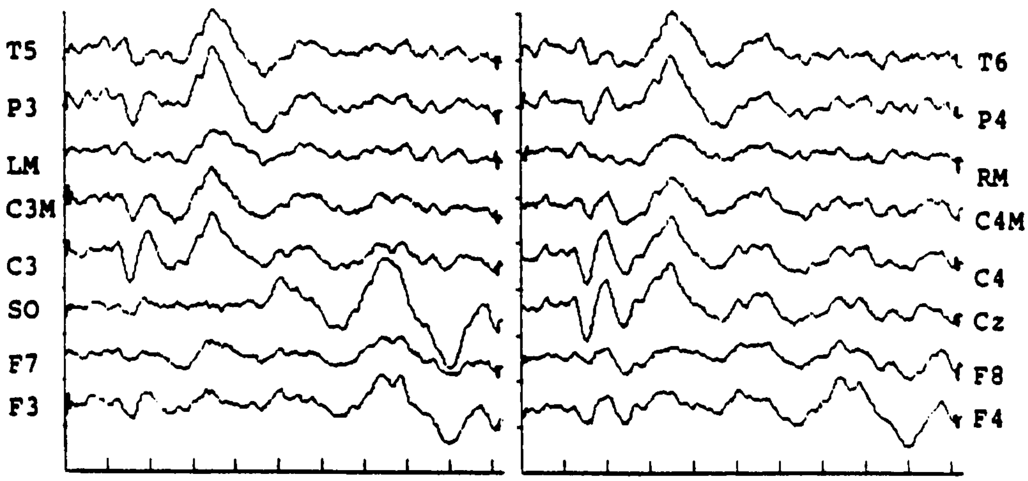
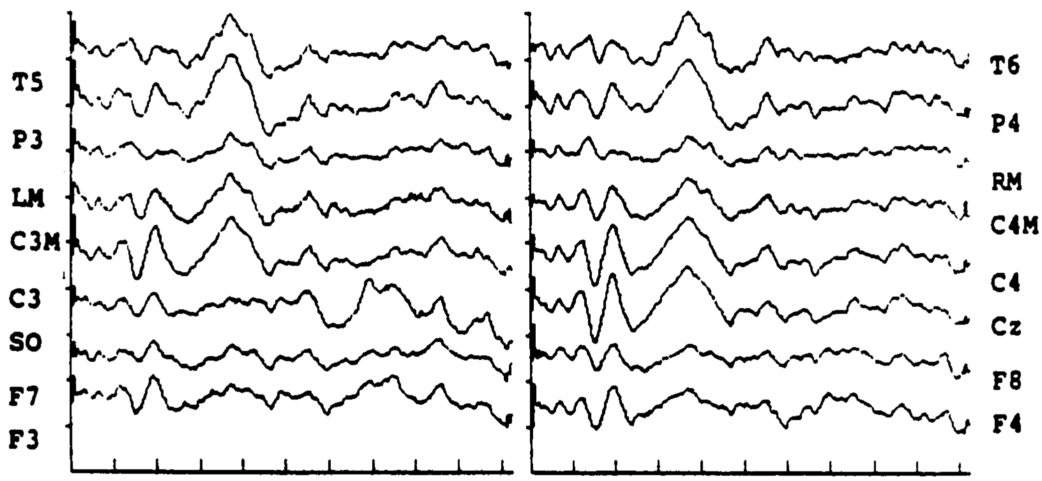
200.000 5.00

SENTENCE CONTEXT CONDITION-PROBE WORDS 1(TOPIC RELATED)



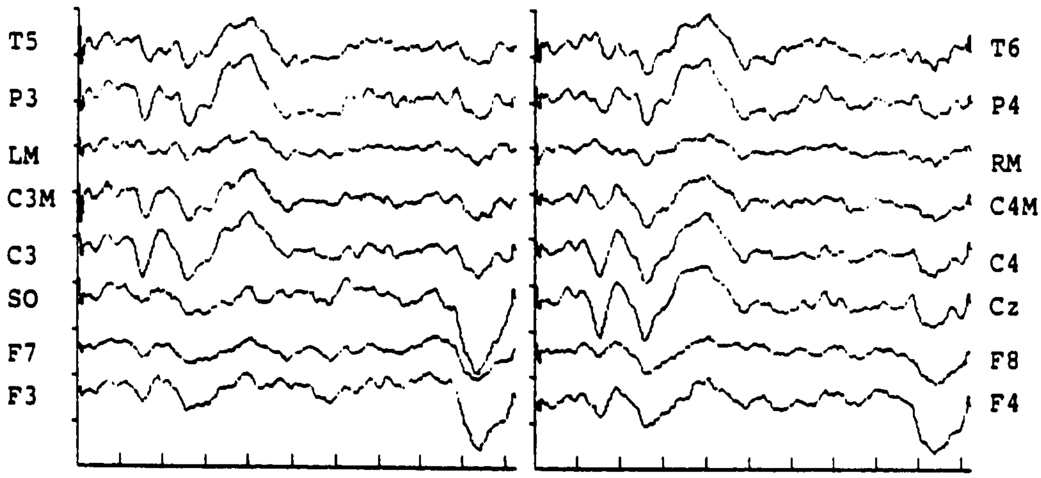
ms/div 200.000 uV/div 5.00

SENTENCE CONTEXT CONDITION-PROBE WORDS 2(RELATED TO LAST WORD)



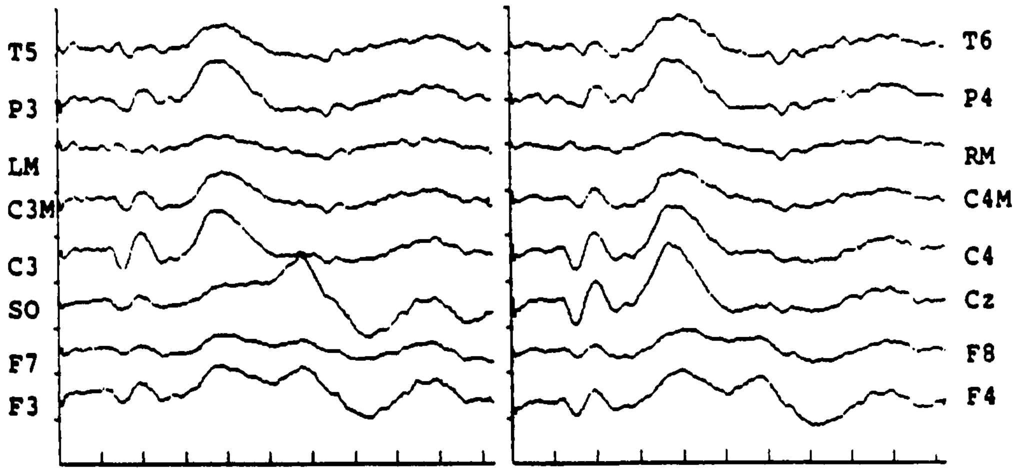
ms/div uV/div
200.000 5.00

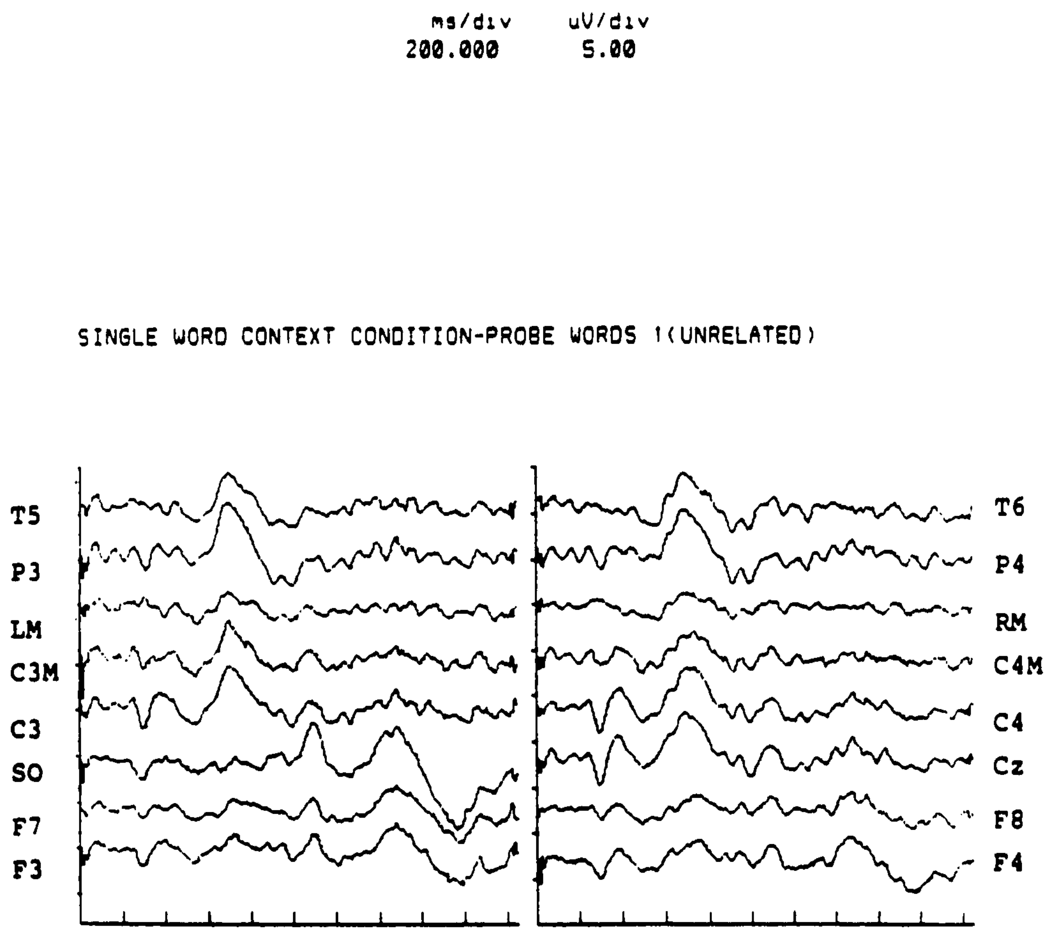
SENTENCE CONTEXT CONDITION-PROBE WORDS 3(UNRELATED)



ms/div uV/div
200.000 5.00

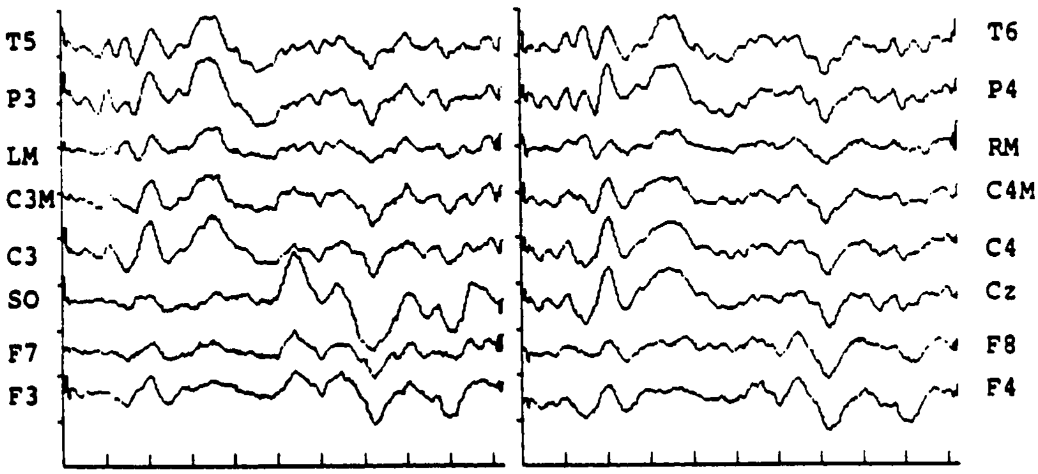
SINGLE WORD CONTEXT CONDITION-NONWORDS




ms/div
200.000
uV/div
5.00
SINGLE WORD CONTEXT CONDITION-PROBE WORDS 1(UNRELATED)
T5
P3
LM
C3M
C3
SO
F7
F3
T6
P4
RM
C4M
C4
Cz
F8
F4

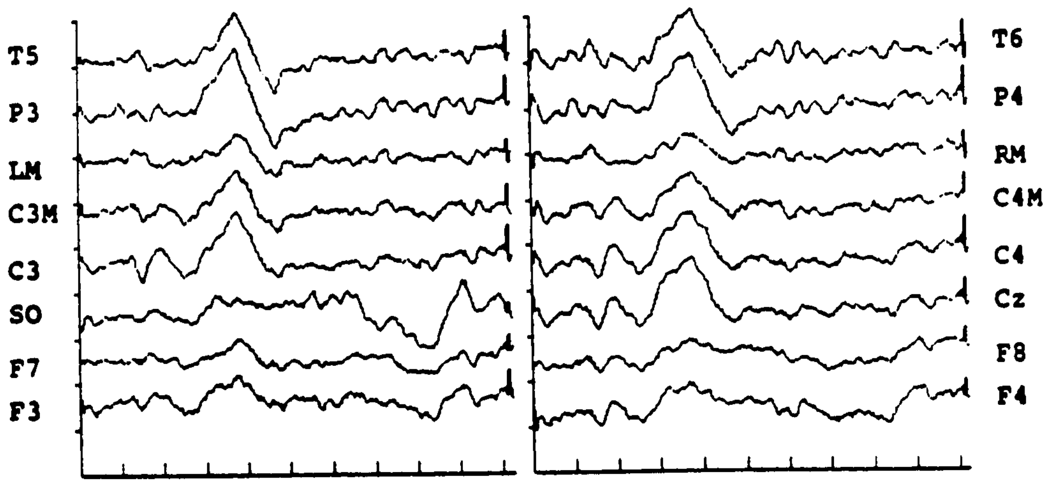
ms/div 200.000 uV/div 5.00

SINGLE WORD CONTEXT CONDITION-PROBE WORDS 2(RELATED)



ms/div 200.000 uV/div 5.00

SINGLE WORD CONTEXT CONDITION-PROBE WORDS 3(UNRELATED)



APPENDIX D

TWO WAY COMPARISONS-SIGNIFICANCE TABLES

(See Table 1 (p. 18) for an explanation of codes.)

Behavioral Study (N=26):	Scheffe-F	p	Tukey HSD
Reaction Time -			
Within Context Condition -			
Sentences 1 < Sentences 2	6.79	.01	.01
Sentences 1 < Sentences 3	40.88	<.001	.01
Sentences 2 < Sentences 3	14.35	<.001	.01
Words 1 > Words 2	13.53	<.001	.01
Words 1 < Words 3	27.53	<.001	.01
Words 2 < Words 3	79.67	<.001	.01
Isolation 1 - Isolation 2	0.92	NS	NS
Isolation 1 < Isolation 3	3.48	.05	NS
Isolation 2 - Isolation 3	0.83	NS	NS
Within Target Type -			
Isolation 1 - Sentences 1	0.14	NS	NS
Isolation 1 - Words 1	0.16	NS	NS
Sentences 1 - Words 1	0.60	NS	NS
Isolation 2 < Sentences 2	3.40	.05	.05
Isolation 2 < Words 2	12.50	<.001	.01
Sentences 2 > Words 2	28.94	<.001	.01
Isolation 3 < Sentences 3	22.51	<.001	.01
Isolation 3 - Words 3	1.58	NS	NS
Sentences 3 > Words 3	12.15	<.001	.01

Electrophysiologic Study (N=10):	Scheffe-F	p	Tukey HSD
Reaction Time -			
Within Context Condition -			
Sentences 1 < Sentences 2	5.15	.05	.05
Sentences 1 < Sentences 3	25.87	<.001	.01
Sentences 2 < Sentences 3	7.93	.01	.01
Words 1 > Words 2	4.27	.05	.05
Words 1 < Words 3	12.69	<.001	.01
Words 2 < Words 3	31.68	<.001	.01
Isolation 1 - Isolation 2	1.69	NS	NS
Isolation 1 < Isolation 3	6.52	.01	.01
Isolation 2 - Isolation 3	1.58	NS	NS
Within Target Type -			
Isolation 1 - Sentences 1	1.27	NS	NS
Isolation 1 - Words 1	0.30	NS	NS
Sentences 1 - Words 1	0.33	NS	NS
Isolation 2 - Sentences 2	0.53	NS	NS
Isolation 2 < Words 2	14.25	<.001	.01
Sentences 2 > Words 2	20.33	<.001	.01
Isolation 3 < Sentences 3	9.19	.01	.01
Isolation 3 - Words 3	.535	NS	NS
Sentences 3 > Words 3	5.29	.05	.05

N1 Amplitude -	Scheffe-F	p
Within Context Condition -		
Sentences 1 - Sentences 2	0.28	NS
Sentences 1 - Sentences 3	0.78	NS
Sentences 2 - Sentences 3	0.12	NS
Sentences NW - Sentences 1	1.12	NS
Sentences NW - Sentences 2	0.28	NS
Sentences NW - Sentences 3	0.03	NS
Words 1 - Words 2	0.21	NS
Words 1 - Words 3	0.03	NS
Words 2 - Words 3	0.08	NS
Words NW - Words 1	0.03	NS
Words NW - Words 2	0.40	NS
Words NW - Words 3	0.12	NS
Isolation 1 - Isolation 2	0.17	NS
Isolation 1 - Isolation 3	0.41	NS
Isolation 2 - Isolation 3	0.06	NS
Isolation NW - Isolation 1	0.38	NS
Isolation NW - Isolation 2	0.04	NS
Isolation NW - Isolation 3	0.00	NS
Within Target Type -		
Sentences 1 - Words 1	2.42	NS
Sentences 2 - Words 2	0.35	NS
Sentences 3 - Words 3	0.15	NS
Sentences NW - Words NW	1.17	NS

P2 Amplitude -	Scheffe-F	p
Within Context Condition -		
Sentences 1 - Sentences 2	0.45	NS
Sentences 1 - Sentences 3	0.13	NS
Sentences 2 - Sentences 3	1.08	NS
Sentences NW - Sentences 1	1.06	NS
Sentences NW < Sentences 2	2.89	.05*
Sentences NW - Sentences 3	0.44	NS
Words 1 - Words 2	0.79	NS
Words 1 - Words 3	0.11	NS
Words 2 > Words 3	1.47	.05*
Words NW - Words 1	0.35	NS
Words NW < Words 2	2.20	.05*
Words NW - Words 3	0.07	NS
Isolation 1 - Isolation 2	0.90	NS
Isolation 1 - Isolation 3	0.66	NS
Isolation 2 - Isolation 3	0.02	NS
Isolation NW - Isolation 1	0.48	NS
Isolation NW - Isolation 2	0.07	NS
Isolation NW - Isolation 3	0.14	NS
Within Target Type -		
Sentences 1 - Words 1	0.16	NS
Sentences 2 - Words 2	0.10	NS
Sentences 3 - Words 3	0.34	NS
Sentences NW - Words NW	0.04	NS

(* - FisherPLSD - .05)

P3 Amplitude at Cz -	Scheffe-F	p
Within Context Condition -		
Sentences 1 - Sentences 2	0.02	NS
Sentences 1 - Sentences 3	0.27	NS
Sentences 2 - Sentences 3	0.13	NS
Sentences NW - Sentences 1	0.89	NS
Sentences NW - Sentences 2	0.62	NS
Sentences NW - Sentences 3	0.18	NS
Words 1 - Words 2	0.14	NS
Words 1 - Words 3	0.02	NS
Words 2 - Words 3	0.26	NS
Words NW - Words 1	0.00	NS
Words NW - Words 2	0.14	NS
Words NW - Words 3	0.02	NS
Isolation 1 - Isolation 2	0.01	NS
Isolation 1 - Isolation 3	0.23	NS
Isolation 2 - Isolation 3	0.34	NS
Isolation NW - Isolation 1	0.62	NS
Isolation NW - Isolation 2	0.79	NS
Isolation NW - Isolation 3	0.09	NS
Within Target Type -		
Sentences 1 - Words 1	2.28	NS
Sentences 2 - Words 2	0.53	NS
Sentences 3 - Words 3	1.03	NS
Sentences NW - Words NW	0.57	NS
Sentences 1 - Isolation 1	0.05	NS
Sentences 2 - Isolation 2	0.05	NS
Sentences 3 - Isolation 3	0.01	NS
Sentences NW - Isolation NW	0.00	NS
Words 1 - Isolation 1	1.69	NS
Words 2 - Isolation 2	0.26	NS
Words 3 - Isolation 3	1.26	NS
Words NW - Isolation NW	0.67	NS

P3 Amplitude at P3 - Within Context Condition -	Scheffe-F	p
Sentences 1 - Sentences 2	0.03	NS
Sentences 1 - Sentences 3	0.00	NS
Sentences 2 - Sentences 3	0.02	NS
Sentences NW - Sentences 1	0.64	NS
Sentences NW - Sentences 2	0.97	NS
Sentences NW - Sentences 3	0.71	NS
Words 1 - Words 2	0.16	NS
Words 1 - Words 3	0.00	NS
Words 2 - Words 3	0.13	NS
Words NW < Words 1	2.54	.05
Words NW < Words 2	1.43	.05
Words NW < Words 3	2.41	.05
Isolation 1 - Isolation 2	0.01	NS
Isolation 1 - Isolation 3	0.05	NS
Isolation 2 - Isolation 3	0.02	NS
Isolation NW < Isolation 1	2.51	.05
Isolation NW < Isolation 2	2.22	.05
Isolation NW < Isolation 3	1.88	.05
Within Target Type -		
Sentences 1 - Words 1	1.47	NS
Sentences 2 - Words 2	0.02	NS
Sentences 3 - Words 3	1.83	NS
Sentences NW - Words NW	0.25	NS
Sentences 1 - Isolation 1	0.06	NS
Sentences 2 - Isolation 2	0.01	NS
Sentences 3 - Isolation 3	0.00	NS
Sentences NW - Isolation NW	0.01	NS
Words 1 - Isolation 1	0.96	NS
Words 2 - Isolation 2	0.27	NS
Words 3 - Isolation 3	1.83	NS
Words NW - Isolation NW	0.35	NS

P3 Latency -	Scheffe-F	p	Tukey
Within Context Condition -			
Sentences 1 < Sentences 2	1.23	NS	.05
Sentences 1 < Sentences 3	4.52	.01	.01
Sentences 2 - Sentences 3	1.03	NS	NS
Sentences NW > Sentences 1	6.61	.01	.01
Sentences NW > Sentences 2	2.13	NS	.05
Sentences NW - Sentences 3	0.19	NS	NS
Words 1 > Words 2	3.52	.01	.01
Words 1 - Words 3	0.07	NS	NS
Words 2 < Words 3	4.61	.01	.01
Words NW > Words 1	0.94	NS	.05
Words NW > Words 2	8.09	.01	.01
Words NW - Words 3	0.48	NS	NS
Isolation 1 - Isolation 2	0.01	NS	NS
Isolation 1 - Isolation 3	0.04	NS	NS
Isolation 2 - Isolation 3	0.78	NS	NS
Isolation NW > Isolation 1	4.90	.01	.01
Isolation NW > Isolation 2	5.21	.01	.01
Isolation NW > Isolation 3	4.01	.01	.05
Within Target Type -			
Sentences 1 - Words 1	2.17	NS	NS
Sentences 2 > Words 2	10.43	.001	.01
Sentences 3 - Words 3	2.24	NS	NS
Sentences NW - Words NW	1.28	NS	NS
Sentences 1 < Isolation 1	11.60	.001	.01
Sentences 2 - Isolation 2	0.71	NS	NS
Sentences 3 - Isolation 3	0.10	NS	NS
Sentences NW - Isolation NW	1.39	NS	NS
Words 1 < Isolation 1	3.74	.01	.01
Words 2 < Isolation 2	16.56	.001	.01
Words 3 - Isolation 3	1.41	NS	NS
Words NW < Isolation NW	5.33	.01	.05

N360 Amplitude -	Scheffe-F	p
Within Context Condition -		
Sentences 1 < Sentences 2	7.80	.01
Sentences 1 < Sentences 3	19.57	<.001
Sentences 2 - Sentences 3	2.66	NS
Words 1 - Words 2	2.20	NS
Words 1 - Words 3	0.12	NS
Words 2 - Words 3	3.36	NS
Isolation 1 - Isolation 2	0.45	NS
Isolation 1 - Isolation 3	0.74	NS
Isolation 2 - Isolation 3	0.04	NS
Within Target Type -		
Sentences 1 - Words 1	1.32	NS
Sentences 2 > Words 2	8.26	.05
Sentences 3 - Words 3	4.17	NS

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