PRIMING PICTURES AND WORDS:
AN INVESTIGATION OF THE N400 AND LPC

By

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Statement

This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any Institution and, to the best of my knowledge, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed ____________

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SEMANTIC AND MNEMONIC PROCESSING:
A REVIEW OF THE N400 AND LPC COMPONENTS OF THE ERP

Literature Review

CONTENTS

Abstract

Two ERP components are discussed in relation to studies of semantic and mnemonic processing, namely the N400 and LPC. The N400 is a monophasic negativity typically observed between 250 - 500 ms post-stimulus. Semantic and repetition priming studies utilising linguistic stimuli in the visual modality (i.e. words, nonwords), and stimulus paradigms (i.e. sentence priming and lexical decision tasks) have indicated that the N400 is readily evoked by semantic anomaly and is sensitive to word frequency (low frequency words eliciting greater amplitude N400's than high frequency words), word class (larger N400's to content words), semantic relatedness (larger N400's to unrelated words), subject expectancy (larger N400's to unexpected words within a context), phonology (larger N400's to non-rhyming words and nonwords), and repetition (attenuated N400's following word repetition). Theoretical formulations suggest the N400 indexes the degree of spreading activation throughout the semantic network (Morton, 1969), contextual integration (Rugg, 1990), semantic expectancy (Kutas & Hillyard, 1984), or a memory search process (Bentin & McCarthy, 1994). Which of these formulations most accurately explains the N400 is currently unresolved. Whether the negativity observed following semantic anomaly in paradigms employing nonlinguistic stimuli (e.g. pictures, faces, and music) is reflecting the same process as the N400 elicited by linguistic anomaly, is also the subject of considerable debate.

Enhanced LPC amplitudes in language tasks are typically recorded to sentence final words. The broad, post N400 positivity, occurs approximately 550-800 ms post-stimulus and is presumed to reflect processes associated with closure (Friedman, Simson, Ritter, & Rapin, 1975; Kutas & Hillyard, 1982), certainty (Stuss, Picton, Cerri, Leech, & Stethem, 1992), and integrative elaborative processing (Andrews, Mitchell, & Ward, 1993). All task relevant stimuli appear to elicit the LPC, its amplitude being inversely related to subjective probability. The LPC is also associated with certain aspects of mnemonic processing. Enhanced LPC amplitudes have been recorded to stimuli which are subsequently recognised, to 'seen' stimuli as compared to 'unseen', and to the second presentations of stimuli. Subsequent to these findings, it has been hypothesised that the LPC observed in memory and repetition paradigms reflects some process associated with both encoding and retrieval. Resulting from the perceived similarity between the LPC component elicited in these various paradigms, some investigators posit that similar episodic processes subserve them (Besson & Kutas, 1993).

INTRODUCTION

Despite continuing technological advances in which the human brain has been subjected to increasingly refined measures, there still exists controversy with regards to the activity, nature, and arrangement of the basic mechanisms subserving linguistic and nonlinguistic comprehension. An advantage conferred upon the more recent central measures of brain functioning is that they are not only able to tap 'on-line' the previously inaccessible cerebral processes, but they are able also to quantify and localise them. By controlling and manipulating certain aspects of the environment (e.g. the linguistic environment), the investigator hypothesises that the subsequent cerebral changes (e.g. blood flow or electrical potentials) are the result of the manipulation. These measures provide information as to the timing, intensity, topographical pattern and duration of the specific process under investigation.

The following review will provide an outline of one particular central measure of brain functioning, the Event Related Potential (ERP), in relation to the processes of comprehension (both linguistic and nonlinguistic). Research in the areas of semantic and repetition priming, and recognition memory in semantic processing tasks will be discussed, focussing particularly on the two components identified within the ERP relating to semantic and mnemonic processing, the N400 and the Late Positive Component (LPC).

EVENT-RELATED POTENTIALS AND LANGUAGE

The ERP, a measure of brain electrical potentials as derived from the electroencephalogram is assumed to reflect the underlying neural activity associated with stimulus processing. It is obtained by averaging the EEG, each time-locked to the presentation of a stimulus, from a number of trials in a given experimental condition. Several components within a defined epoch have been identified and each "component is presumed to reflect activation of a neuronal ensemble and their time course of activation determines the distribution of voltage over the scalp" (p. 130, Bentin & McCarthy, 1994). By recording over a multitude of scalp sites, the investigator is able to delineate the various components present (varying in amplitude, latency, and scalp distribution) in response to a particular stimulus.

One component specifically identified as relating to studies of language comprehension is the N400, the origin and function of which is still relatively unresolved. The section below provides an overview of the N400 component in a variety of linguistic and nonlinguistic paradigms.

N400 COMPONENT

Over the past decade or so, ERPs have become increasingly popular as a means of investigating the process of language comprehension (Kutas & Hillyard, 1980a; 1980b; 1984; 1989; Fichsler, Bloom, Childers, Roucos, & Perry, 1983; Bentin, McCarthy, & Wood, 1985; Rugg, 1985; 1987; Kutas & Van Petten, 1988; Van Petten & Kutas, 1990; 1991). One of the most relevant discoveries in this domain is the N400 component which is described as a monophasic negativity between 250 and 500 ms post-stimulus, whose amplitude is inversely proportional to expectancy within a semantic context (Kutas & Hillyard, 1984; Bentin, 1987; Kutas, Van Petten, & Besson, 1988; Besson, Kutas, & Van Petten, 1992).

Much of the evidence suggesting a role for the N400 in indexing aspects of language comprehension has come from semantic priming studies. Priming, traditionally indexed by the RT measure, can be defined as the "facilitation given by the presentation of one item (the prime) to a response to an immediately following test item [the target]" (p. 386, Ratcliff & McKoon, 1988). Semantic priming is viewed as the facilitation of recognition of an item which has been preceded by a semantically related item. For example in a typical lexical decision task (LDT), if the word *'salt'* (the prime) preceded presentation of the word '*pepper*' (the target), recognition of the target would be facilitated (responses are faster, and N400 amplitude is attenuated). In contrast if the prime '*salt*' was followed by the target '*chair*', RT would be slowed and N400 amplitude would be increased relative to the expected target (Sanquist, Rohrbaugh, Syndulko, & Lindsley, 1980; Harbin, Marsh, & Harvey, 1984; Boddy, 1986; Bentin, 1987; Bentin & McCarthy, 1994).

In paradigms utilising sentences, recognition of sentence final words is seen to be facilitated when congruous with the biasing context (e.g. "*He mailed the letter without a stamp*"). When a sensible and syntactically legal sentence is concluded by an unexpected (or incongruous) word (e.g. "*He mailed the letter without a drill*") RT is seen to be slower and N400 amplitude is enhanced (Kutas & Hillyard, 1980a, 1980b; 1982; 1983; 1984; 1989; Van Petten & Kutas, 1990; 1991; Nigam, Hoffman, & Simons, 1992; Woodward, Ford, & Hammett, 1993).

Whereas the largest N400s are elicited by semantic incongruity, several studies have demonstrated that all words elicit an N400 (Kutas & Hillyard, 1984) and that lexical constraint, sentential constraint, and word frequency (Fichsler et al., 1983; Besson et al., 1992; Rugg, 1990; Van Petten & Kutas, 1990; 1991; Young & Rugg, 1992; Otten, Granot, & Donchin, 1994) all contribute to determine the amplitude of the N400.

The response facilitation observed in priming tasks is taken as evidence to suggest that the entries in one's mental 'dictionary' are clustered in some meaningful fashion. Those that align themselves with the network model of semantic representation (Collins & Quillian, 1969; Collins & Loftus,

1975) explain the priming phenomenon in terms of the 'spreading activation' conceptualisation. This model suggests that processing a concept temporarily activates that concept, and closely related concepts, as activation automatically spreads from link to link (or node to node) throughout the semantic network (Posner & Snyder, 1975). Maximal activation is perceived to occur in the closest set of nodes (Collins & Loftus, 1975). An opposing view is that of Ratcliff and McKoon's (1988) compound-cue retrieval model which describes priming in terms of the formation of a 'compound' (the target and context) in a short-term store whose familiarity is compared to the long-term store representation. Priming, according to this model, therefore is the result of a search through memory: the more familiar the compound, the greater the priming effect. Evidence has been provided both for and against each model, yet to this date most investigators appear to align themselves with the spreading activation account of priming (Boddy & Weinberg, 1981; Kutas & Hillyard, 1989; Besson et al., 1992; Brown & Hagoort, 1993; Chapnik-Smith, Besner, & Myoshi, 1994; McNamara, 1994).

The issue of the relative contribution of automatic and attentional processes in producing the observed response facilitation in priming paradigms is unresolved. Posner and Snyder's (1975) influential two-process theory suggests that automatic processes (such as the spread of activation through the semantic network) are unconscious and strategy independent, operating in parallel with other mental activities with no interference. Attentional processes are thought to integrate the output of multiple automatic processes, and are limited in capacity and slower. In support of the two-process system of priming, Neely (1977) found evidence of semantic priming at short intervals in a LDT, despite subject expectancies contradicting such related pairings. Challenging this finding, Chapnik-Smith et al. (1994) conducted a LDT manipulating stimuli duration which provided strong evidence for the position that semantic priming depends on the depth of processing (depth referring to the degree of semantic involvement; Craik and Tulving, 1975) and the context in which a word is read, indicating that strategic factors are likely to impact on the process.

Whether the N400 reflects the automatic component described by Posner and Snyder (1975), or is related to less automatic, decision-related processes has been the subject of much experimentation. In tasks which have systematically varied subject attention (Kutas & Hillyard, 1989), spatial selective attention (McCarthy & Nobre, 1993), perceptual identification (i.e. masking studies, Brown & Hagoort, 1993), interstimulus interval (Boddy, 1986), the proportion of semantically congruous/related stimuli (Holcomb, 1988), task relevance (Mitchell, Andrews, Fox, Catts, Ward, & McConaghy, 1991) and task demands (i.e. depth of processing, Neville, Kutas, Chesney, & Schmidt, 1986), the overall conclusion is firstly that there is a sizeable attentional component to the semantic priming effect, and secondly, that the N400 primarily reflects this attentional aspect (i.e. the conscious comprehension of target stimuli associated with contextual integration (Holcomb, 1993; Brown & Hagoort, 1993; McCarthy & Nobre, 1993; Chwilla, Hagoort, & Brown, 1994)). Consequently, the more difficult it is to integrate a given piece of information with the preceding context, the larger the N400 (Rugg, 1990; Holcomb, 1993; Rugg, Doyle, & Holdstock, 1994). Not being directly related to comprehension per se, integration is "assumed to build the representation(s) that provides the basis for comprehension, and the N400 is assumed to be directly proportional to the effort required by this process to fit each item into the representation..." (p. 60, Holcomb, 1993).

Other investigators perceive the N400 component as reflecting those processes subsumed within a strategic memory search (Stuss, Sarazin, Leech, & Picton, 1983; Stuss, Picton, & Cerri, 1986; Stuss, Picton, Cerri, Leech, & Stethem, 1992). As a result, the greater the number of possible interpretations that need to be searched (i.e. in a more ambiguous context), the larger the amplitude of the N400 (Stuss et al., 1992). In line with Stuss and colleagues (1983; 1986; 1992), Bentin and McCarthy (1994), offer the suggestion that the N400 is related to the search for meaning of both verbal and nonverbal stimuli (i.e. accessing semantic memory), rather than to the activation of meaning. Evidence to support this account arose from their finding of substantial N400s to first presentations of stimuli which required access to semantic memory (i.e. faces, words, and letters) while no such effects were elicited in the tasks which could be performed without access to the meaning of the stimuli (i.e. word-number and face-nonface discrimination). They viewed the effects of repetition in abolishing the N400 as due to the fact that on immediate repetition the initial response was still available (in short-term memory) and therefore no controlled access to semantic memory was necessary.

Many questions still remain unanswered in the domain of language comprehension. For example, which properties of the stimuli are actually being represented in memory and in what form (propositions? Anderson 1983); what is involved in integrating a stimuli with its context, and what makes it easy or difficult (Rugg, 1990); and finally, what is the actual contribution of residual episodic traces to the amplitude of the N400? (Stuss et al., 1992; Bentin & McCarthy, 1994). The following sections will detail experimentation in a variety of language and nonlanguage paradigms, the aim being to provide a profile of the N400 component.

N400 Component in Sentence Paradigms

1. Expectancy

The 'classic paradigm' employed to elicit the N400 is the termination of a logical sentence with unpredictable and semantically incongruous words (Kutas & Hillyard, 1980a). Schwanenflugel and LaCount (1988) comment that there are three important relations between the sentence and its final word: the congruity of the word within the sentence context, the degree of sentential constraint, and word-level expectancy. Kutas and Hillyard (1984) manipulated both the degree of sentential constraint and the word-level expectancy and comment that the high constraint sentences tended to yield larger context effects than the low constraint sentences. Also, words with a high 'cloze probability' (the "proportion of subjects using that word to complete a particular sentence" p. 161) evoked smaller amplitude negativity than those with a lower cloze probability (the amplitude of the N400 component being an inverse function of the subject's expectancy for the terminal word). They concluded within the framework of the activation model (Morton, 1969, Collins & Loftus, 1975) that N400 amplitude varied "according to whether or not an unexpected terminal word is semantically related to the most expected ending of the sentence" (p. 162, Kutas & Hillyard, 1984). The activation model also predicts that all words in a sentence should be associated with an N400 with amplitude decreasing across word position as increasing contextual constraint provides greater degrees of 'top-down' activation (Nigam et al., 1992; Van Petten & Kutas, 1990; 1991).

Fichsler et al. (1983) compared ERPs elicited by incongruity based in semantic, episodic and personal knowledge. Subjects were instructed to verify a set of simple semantic propositions which were divided into the following categories :

True Affirmative:	"A robin is a bird"
False Affirmative:	"A robin is a vehicle"
True Negative:	"A robin is not a vehicle"
False Negative:	"A robin is not a bird"

The final words of the false affirmatives and true negatives were observed to elicit an N400, allowing them to conclude that the N400 did not reflect the truth or falsity of the proposition, but the associative (semantic) relationship between the content words. This result is congruent with the proposal that the N400 is determined by the degree to which the preceding sentence fragment has 'primed' the word.

2. Grammatical deviation

Apart from the N400 component indexing word expectancy in a sentence context, the impact of nonsemantic variation was investigated in an attempt to delineate the types of linguistic deviations that elicited it. Kutas and Hillyard (1983) presented subjects with prose passages containing semantic and grammatical anomalies (i.e. errors in verb tense or the incorrect use of a singular or plural noun or verb). As expected, semantic deviations (in intermediate or sentence final positions) elicited the N400 while grammatical deviations elicited a far smaller and more frontally distributed negativity.

Van Petten and Kutas (1991) recorded ERPs while subjects read semantically meaningful sentences, syntactically legal but nonsensical, and random word strings in order to assess whether the N400 was sensitive to syntactic constraints. The absence of the N400 in syntactically legal but nonsensical and random word strings suggests its insensitivity to syntactic constraints. The above two studies further illustrate the specificity of the N400 to semantic deviation in linguistic contexts.

3. Word Frequency

A frequency related difference in N400 amplitude has been consistently reported (Rugg, 1990; Van Petten & Kutas, 1990; 1991; Besson et al., 1992; Young & Rugg, 1992) in which N400 is enhanced for low frequency words as compared to high frequency words. This finding parallels behavioural evidence indicating that the speed and accuracy of performance is enhanced the greater the frequency of a word's occurrence in language

(Monsell, Doyle, & Haggard, 1989). The finding of an interaction between word frequency and repetition on N400 amplitude (Besson et al., 1992) is similar to the observed interaction between word frequency and sentence context (Van Petten & Kutas, 1990; 1991). With one repetition, or as sentential context increases, the ERP difference between low and high frequency words is attenuated. As to the time course of the effects of word frequency versus semantic constraint, Van Petten and Kutas (1991) postulated that the language comprehension process is flexible and adaptive enough to be able to use the best information available at any point in time (i.e. sentence context or word frequency). This perspective is in agreement with Marslen-Wilson's (1987) interactive-parallel model of language comprehension.

4. Nonlinguistic stimuli

An extensive body of research has investigated the processing differences demanded by words and pictures (Durso & Johnson, 1979; Stuss et al., 1983; Stelmack, Plouffe, & Winogron, 1983; Vanderwart, 1984; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986; Bajo, 1988; Theios & Amrhein, 1989; Barrett & Rugg, 1990; Noldy, Stelmack, & Campbell, 1990; Stelmack & Miles, 1990; Nigam et al., 1992) and generally the literature appears to support the broad contention that pictures activate a semantic/meaning code prior to lexical access, resulting in latency delays in picture naming as compared to word naming (Potter & Faulkoner, 1975). The dual code model of Paivio (1971) and the sensory-semantic model of Nelson, Reed, and McEvoy (1977) attempt to explain the processing differences of verbal and nonverbal stimuli and the memory advantage afforded when both systems (sensory and semantic) are utilised concurrently. Pictures are therefore better remembered than words because they are believed to be represented both visually and verbally (Noldy et al., 1990).

The distinction between the mental lexicon (storing knowledge about words) and an amodal conceptual system (representing conceptual knowledge independent of modality; Nigam et al., 1992) is important in the comparison of word versus picture processing. Potter et al. (1986) provide evidence for the distinction between surface-form and conceptual systems and comment that both systems operate according to task demands. For example in a task demanding lexical access (e.g. replacing words with pictures in sentences), pictures are processed markedly slower than words. Yet in a conceptual task (e.g. semantic categorisation), pictures and words are understood equally fast (with a slight advantage for pictures; Snodgrass, 1984).

ERP's studied in relation to language processing utilising linguistic stimuli have been applied increasingly to nonlinguistic stimuli. Following such investigations, one is able to make comparisons between the semantic processing of words, and the semantic processing of stimuli which do not possess lexical attributes, extending into localisation of key areas of activity, scalp distribution, amplitude and latency differences, and also effects on retrieval processes.

A few ERP studies have conducted within-subjects comparisons of linguistic and nonlinguistic stimuli and results are mixed with regards to whether the N400 component is elicited by unexpected nonlinguistic stimuli (i.e. pictures) in the same manner as linguistic (i.e. words). As with all experimental comparison, difficulty emerges with variations in task design, subject demands, stimuli characteristics (e.g. size, colour, complexity), recording procedures, subject population etc.

Nigam et al. (1992) replicated the Kutas and Hillyard (1980a) sentence paradigm but replaced the terminal word with a picture representing the same concept. They found that the N400 generated by the unexpected pictures were identical to those shown by unexpected words in terms of amplitude, scalp distribution, and latency. The authors take this as evidence that the N400 is an index of activity in a conceptual memory that is accessed by both pictures and words.

Besson and Macar (1987) failed to elicit the N400 with nonlinguistic versions of the sentence paradigm - namely geometric patterns ordered in increasing size, ascending scale notes, and well known French melodies. In an explanation of the absence of an N400 component to deviant endings, the authors comment on the simplicity of their geometric and music stimuli and suggest no further processing may have been necessary following the simple mismatch. These results suggest that two variables necessary for N400 activity are the existence of prior memory representations, and the demand for further processing beyond simple detection of a mismatch.

Paller, McCarthy, and Wood (1992) also failed to elicit the N400 potential in a nonlinguistic analogue of the design used by Kutas and Hillyard (1980a). Well known French melodies were concluded with either an expected note or a different note, allowing for more processing time than the Besson and Macar (1987) study. In no instance did the deviant note elicit an N400-like waveform. Levett and Martin (1993) however, recorded a sizeable N400 to musical errors (i.e. 4 part Bach chorales) in a musician population, compared to no N400 in a non-musician population. This suggests that the investigation of musical N400s is not yet resolved. The elicitation of an N400 waveform utilising musical stimuli may require a substantial degree of familiarity with the composition and structure of music, such as would be held by a trained musician. The similarity between music, mathematics, and linguistics is an area for future investigation; any conclusion that the N400 is solely restricted to linguistic violations would be premature.

As is evident from the preceding review, the N400 component can be reliably elicited by a large variety of meaningful stimuli in the sentence paradigm. The role of subject expectancy and contextual integration appears to dominate explanations of the aetiology of the post-target negativity. One aspect that has not been covered though is the variation in scalp distribution of the N400 resulting from different stimuli and task parameters. The topography of the N400 will be reviewed following the next section, which provides an overview of the literature to date focussing on the N400 in nonsentential paradigms (namely semantic categorisation and matching tasks). Evidence of substantial N400s in such paradigms further extends the generalisability of the component to nonsentential contexts using both linguistic and nonlinguistic stimuli.

<u>N400 and Nonsentential Contexts</u>

1. Word Pairs and Lists

Debate exists as to whether ERPs elicited by unmatched/unexpected stimuli in tasks of semantic categorisation (Boddy & Weinberg, 1981; Polich, Vanasse, & Donchin, 1981; Polich, 1985a, 1985b; Harbin et al, 1984; Deacon, Breton, Ritter, & Vaughan, 1991; Young & Rugg, 1992), and phonological matching (Sanquist et al., 1980; Polich, McCarthy, Wang, & Donchin, 1983; Rugg, 1984; Kutas & Van Petten 1988) are essentially the same as those elicited through semantic anomaly.

A significant number of investigators have, however, observed N400s in the ERPs to single words within a series of words. Sanquist et al. (1980) conducted an experiment based on the principle of levels of processing (Craik & Lockhart, 1972; Craik & Tulving, 1975) in which on each trial two words were judged to be the same or different according to a semantic ('deep', *red - blue*), orthographic (shallow, e.g. *red - red*), or phonemic ('intermediate' *red - bed*) criterion. Despite their primary concern with P300 amplitude, inspection of the waveforms for the semantic task reveals a sizeable negative peak to the 'different' judgement (e.g. to *red - lemon*) in the N400 latency range.

Harbin et al. (1984) compared ERPs of young and elderly subjects to the final word of a series of five. The task involved reading each series of words (series consisted of either identical words [e.g. *lemon lemon lemon lemon lemon*]or semantically related words [e.g. *melon apple pear grape orange*]) which were concluded by a mismatched target word 15% of the time (e.g. *melon apple pear grape dog*). For the young population matched words produced larger positivity than mismatched; the mismatched in the category condition producing negativity in the N400 latency range. The authors compare this negativity to that found to incongruous sentence final words (Kutas & Hillyard, 1980a) and comment that "it would appear that N400 results from departure from a recently established semantic context" (p. 495).

Bentin et al. (1985) presented subjects with a continuous list of words intermixed with psuedowords (LDT), some words were preceded by semantic associates ('primed'), some were not. The ERPs to unprimed words were less positive than those for primed words during an epoch that began at about 250 ms and persisted until about 600 ms. They concluded that this negativity was similar to that seen in a series of studies reported by Kutas and Hillyard (1980a; 1980b; 1982; 1984) in which sentences were concluded by semantically anomalous or congruent words . Extending this result, Kutas and Hillyard (1989) found that ERPs to target words in each associated pair actually varied as a function of semantic association. N400 amplitude increased as the degree of semantic association between it and the target word decreased.

The above results, in addition to the findings of McCarthy and Nobre (1993), Bentin (1987), Brown and Hagoort (1993), Rugg (1984; 1985), and Koyama, Nageishi, and Shimokochi (1992) suggest that the negativity elicited to unmatched words in word matching and semantic categorisation tasks is comparable to that elicited by incongruous sentence final words.

2. Nonlinguistic stimuli

In a similar fashion to nonlinguistic stimuli presented within a sentence context, unprimed nonlinguistic stimuli in matching and categorisation tasks have also been indexed by the N400 component (Stuss et al., 1983; Stuss et al., 1986; Ellis, Young, Flude, & Hay, 1987; Friedman, Sutton, Putnam, Brown, & Erlenmeyer-Kimling, 1988; Barrett, Rugg, & Perrett, 1988; Barrett & Rugg, 1989; 1990; Stuss et al., 1992). Stuss et al. (1983) examined the ERP correlates of word reading, picture naming, and mental rotation. In the nonlinguistic, nondeviant condition their subjects were required to judge whether two complex geometrical figures were identical or mirror images. The ERP's recorded evoked a prominent negativity, peaking at 421 ms regardless of whether they were judged to be the same or different. The negativity appeared to be evoked by the task of mental rotation itself. These findings are at odds with the literature, in that broad posterior negativity's were recorded across all tasks (words and figures). Kutas and Van Petten (1988) comment that this discrepancy may be the result of differences in the physical characteristics of the stimuli used (e.g. size). Future investigations comparing linguistic and nonlinguistic stimuli of the same physical parameters (i.e. size, contrast, complexity) should clarify such issues.

Stuss and colleagues recorded a frontal negativity and posterior positivity in a picture naming task (Stuss et al., 1986), and a fronto-central negativity in a picture completion task (Stuss et al., 1992). The amplitude of the negativity (N400) was directly related to the number of pictures possible in the Stuss et al. (1986) study, and the degree of completion of the pictures in the Stuss et al. (1992) study. In both cases, the authors postulated that the amplitude of the N400 may represent either the activation or activity of a search through semantic memory.

A series of experiments conducted by Barrett, Rugg, and colleagues utilising familiar and unfamiliar faces as stimuli in a matching task (Barrett et al., 1988; Barrett & Rugg, 1989) and pictures in a matching task (Barrett & Rugg, 1990) found support for the elicitation of N400 with unprimed nonverbal stimuli which suggests linguistic and nonlinguistic stimuli share a common neural substrate. These studies arose from the general consensus that priming occurs in a similar fashion to pictures as with words (i.e. within-form) and also the agreement that "access of semantic information about a picture does not depend upon the retrieval of its name, implying that pictorial semantic priming effects are unlikely to be verbally mediated" (p. 203, Barrett & Rugg, 1990). Stelmack and Miles (1990) also provided strong evidence for the comparable nature of picture and word ERPs and the existence of an amodal conceptual system (Nigam et al., 1992). Priming a word by an associated picture was observed to reduce N400 amplitude, replicating previous behavioural evidence of cross-form priming (see Vanderwart, 1984).

Therefore, as with the sentence paradigms referred to previously, evidence from the matching and categorisation tasks suggests that both linguistic and nonlinguistic stimuli deviating from the prime are capable of enhancing N400 amplitude. The view that both pictures and words access an amodal conceptual system is congruent with the N400 results. Do unmatched/out of series stimuli which supposedly possess no prior internal semantic representation (e.g. nonwords) elicit an N400 though? The following section reviews those studies investigating this issue.

3. Nonwords

The ability of orthographically legal nonwords to elicit the N400 component has been the subject of considerable investigation (see Rugg, 1984; 1987; Rugg, Furda, & Lorist, 1988; Nagy & Rugg, 1989; Holcomb, 1993; Bentin & McCarthy, 1994). Evidence of an N400 component to nonwords in lexical decision tasks would reinforce the position that the N400 does not reflect lexical access, but processes subsequent to lexical access. Nor would it suggest that N400 depends on linguistic processing at the semantic level.

Rugg (1984) utilised words and nonwords in a phonological matching task which required subjects to discriminate (yes/no response) between equally occurring rhyming and nonrhyming pairs. Both words and nonwords in the nonrhyming condition elicited centrally distributed negativity's in the N400 latency range. The author took this as evidence to suggest that items with no lexical or semantic representation (i.e. nonwords) are capable of being primed and that the N400 "is elicited by a stimulus that does not conform to the 'expectancy' created by a priming event" (p. 442, Rugg, 1984). Whether any semantic processing occurs following the presentation of nonwords is unknown. Phonological information is accessed from nonwords (as evidenced in the Rugg, 1984 study), and it may be the case that subjects access the lexicon according to the nonword's similarity to a word. When a search of the lexicon reveals no such word exists, the phonological attributes may then be sufficient to establish an intermediate level of evaluation (i.e. phonological match/mismatch). In view of this experimental context, subject expectancy would be based upon phonological decision-making, an unexpected mismatch resulting in the elicitation of the N400 component.

If the N400 component can be evoked when phonologically unmatched nonwords are used as stimuli, is it then possible that a more physical discrimination between stimuli could have a similar effect on the

ERP? Bentin and McCarthy (1994) recorded enhanced negativity's to first presentations of stimuli in lexical decision (words and nonwords), face recognition (familiar and unfamiliar) and letter search tasks. They viewed such tasks as demanding a considerable degree of decision-making processes and access to semantic memory. In contrast, when subjects were required to make word/number and face/nonface discriminations, tasks which they perceived as requiring a nonsemantic, physical discrimination rather than a deeper semantic comparison, no N400 was elicited. The authors concluded that attention to the task (McCarthy & Nobre, 1993) and some depth of stimulus processing is required (Rugg et al., 1988). The presence of the component to nonwords and unfamiliar faces suggests that rather than reflecting lexical access, it reflects access to the semantic structure. The attenuation of the N400 is viewed as the partial activation of the semantic structure accessed previously by the context/repeated stimulus, enhanced amplitudes resulting from the poor fit of the unprimed stimulus to its context.

Continuing within-subject investigation of the N400 component under varying task parameters (sentences, lexical decision, verification, and category judgments), with various linguistic and nonlinguistic stimuli (words, nonwords, faces, pictures, music, numbers and abstract line drawings), with different stimulus modalities (auditory, tactile and visual), and with varying stimuli characteristics (size, colour, shape, contrast, complexity) will ultimately reveal the nature of the N400 component and its ability to index semantic anomaly within a multitude of stimulus domains.

N400 Topography

The temporal and topographical characteristics of the N400 tend to vary slightly according to the stimuli and parameters utilised. The majority of studies utilising linguistic stimuli in either a word or sentence context record a parieto-central, right hemisphere negativity between 250 and 600 ms (Kutas & Hillyard, 1983; Deacon et al., 1991; McCarthy & Nobre, 1993; Curran, Tucker, Kutas, & Posner, 1993). In contrast Stuss et al. (1983) found that a negativity of a similar latency elicited by isolated words in a naming task was larger over frontal sites. Similarly Boddy (1986) recorded a more fronto-central negativity in the N400 latency range in a lexical decision task with a left greater than right hemisphere asymmetry.

The variability of these language related negativity's is typically attributed to measurement confounds produced by overlapping components (i.e. an overlapping P300, Stuss et al., 1986; Kutas et al., 1988). Kutas et al. (1988), in an analysis of the lateral asymmetry of the N400 during the silent reading of sentences found that task changes (such as the faster presentation of words) resulted in topographic changes. Unprimed words presented at a rate where 200 ms or less separated the stimuli resulted in a more frontal distribution than those presented at slower rates. Similarly N400s recorded in tasks where some decision was required as to the appropriateness of a statement resulted in a frontal negativity with an earlier peak latency (Neville et al., 1986). Kutas et al. (1988) attribute this to the overlap of a decision/response-related positive component (LPC).

Those studies utilising nonverbal stimuli (such as pictures and faces) have often recorded more frontal N400s (Polich et al., 1981; Barrett et al., 1988; Friedman et al., 1988; Barrett & Rugg, 1989; 1990; Stelmack & Miles, 1990). Nigam et al. (1992), however, recorded a parieto-central N400 to incongruous pictures concluding sentences (identical to the negativity elicited by incongruous terminal words). The difference between this paradigm and others utilising nonverbal stimuli (Stuss et al., 1983; Stuss et al., 1986) is that the stimuli used by Nigam et al. (1992) were considered to be meaningful, readily interpretable, and placed within a linguistic context.

As the above discussion has indicated, the relatively variable nature of the N400 component with regards to the eliciting stimuli and the resultant scalp distribution has resulted in considerable debate as to whether or not it is merely a delayed N2 component. Kutas and Hillyard (1980a; 1980b) considered the possibility that the N400 was a delayed N2, but rejected it on the grounds that, firstly the N400 was not followed by a P300 (i.e. no difference was observed between the subsequent positivity of congruous and incongruous target words), and secondly that the two components have different scalp distributions. Challenging these arguments though, firstly Polich et al. (1981) and Polich (1985a) showed that if subjects had to make a judgement about the category of a word, the negativity was followed by a P300, and secondly Deacon et al. (1991) found no difference between the topographies of the N400 and N2 (see also Bentin et al, 1985; Neville et al., 1986).

Deacon et al. (1991) did find evidence however of a greater effect of semantic priming on N400 amplitude than the N2, and the ease with which N2 latency is manipulated (see Naatenan & Gaillard, 1983) is not observed with the N400 (Kutas & Hillyard, 1984). Far from being resolved, a factor considered important for both the N2 and the N400 is the latency of the subsequent LPC (Rugg, 1984). The following section is an overview of the LPC elicited during semantic discrimination and memory tasks.

LATE POSITIVE COMPONENT

P300

The complexity of the P300 component of the ERP is evidenced by the numerous labels attached to it and the various latencies and scalp distributions it exhibits. The 'classic' P300 can easily be elicited in what has come to be called the 'oddball' paradigm in which a series of events can be judged in relation to membership of one or two categories, these categories having a different probability of occurrence (thus being labelled 'rare' or 'common'). In such a paradigm, the rare category tends to elicit a large parietal P300, the amplitude of which is inversely related to the subjective probability with which the category occurs. In a similar fashion as the N400, the P300 can be characterised as a response to deviance. In contrast to the N400 however, the P300 tends to be elicited when the deviation is physical (i.e. size, colour, or tone) rather than semantic, being classified as a general reaction to suprising, low (subjective) probability events (see Donchin & Fabiani, 1991; for a review).

Following the extension of ERP measurements into the realm of language and memory tasks, several positivities have been identified between the latencies 200-600 ms (Friedman, Vaughan, & Erlenmeyer-Kimling, 1981), various labels being applied according to the paradigms in which they have been observed. The term 'Late Positive Component' (LPC) has been applied to encompass a wide range of positivities which are sensitive to a range of variables. Variations in LPC amplitude are proposed to reflect 'context updating' (Donchin, 1981), elaborative processes (Neville et al., 1986) or contextual closure (Friedman, Simson, Ritter, & Rapin, 1975). The following section will review evidence for the existence of a distinct post-N400 positivity in tasks involving the semantic evaluation of stimuli.

<u>LPC's in Semantic Priming Paradigms</u>

1. Sentences

Friedman et al. (1975) reported an association between the LPC and linguistic processing in a sentence paradigm that was later to be replicated and extended by Kutas and Hillyard (1980a). The authors attributed the enhanced LPC to sentence final words as relating to 'syntactic closure'. In later studies, similar to the Friedman et al. (1975) investigation, the N400 elicited by semantically inappropriate final words was seen as being superimposed upon a centro-parietal positive-going shift (Kutas & Hillyard, 1982; 1983; Harbin et al., 1984; Mitchell et al., 1991; Andrews, Mitchell, & Ward, 1993; Woodward et al., 1993). In a similar fashion to Friedman et al. (1975), the amplitude of the wave was interpreted as being related to syntactic closure (Kutas & Hillyard, 1982; 1983; Van Petten & Kutas, 1991), integrative elaborative processing (Andrews et al., 1993), or some other aspect of sentence completion (Roth & Boddy, 1989). Giving weight to the closure interpretation, the recording of ERP's to intermediate position incongruous words (i.e. prior to sentence completion) by Kutas and Hillyard (1983) revealed no positive swing following the N400.

More recently, Curran et al. (1993) mapped the electrical activity of the brain while subjects read sentences ending either congruously or incongruously. Following the N400 elicited by the incongruous final word, they recorded a strong LPC from about 500 ms. The congruous word elicited an early LPC, so it appeared that the presence of an incongruous and unexpected stimulus delayed the onset of the positivity until the unexpected stimulus had been recognised. Similarly Polich (1985a; 1985b) referred to an LPC following an earlier negativity in judgement paradigms using verbal stimuli (see also Sanquist, et al., 1980; Boddy & Weinberg, 1981; Polich et al., 1981; Bentin et al., 1985). Polich (1985b) found that by varying task demands in two linguistic paradigms (sentences and semantic categorisation) the components elicited depended on whether subjects had to either read the stimulus materials, or make a button-press response judgement about the final word. In the reading task, both paradigms elicited a fronto-central N400-like component to the odd ending target word. In the judgement task however, a clear negative component was followed by a robust LPC. This finding stresses the importance of task instruction/demands on the elicitation of the LPC. Tasks requiring an active decision tending to result in a post-recognition positivity, indexing closure/resolution of uncertainty.

2. Word Pairs and Lists

In a similar fashion to sentence paradigms, the presence of a post N400 positivity in categorisation and matching tasks has also been established (see Rugg, 1984; 1985; Harbin et al., 1984; Noldy et al., 1990). In a phonological matching task Rugg (1984) recorded shorter latency LPC's to rhyming stimuli (words and nonwords). This raised the possibility that the N400 (evoked by nonrhyming stimuli) was confounded by the differences in the onset time of the LPC. Because each component exhibited different scalp topographies (LPC was not markedly asymmetric and maximal at Pz, while N400 was most distinct at the right temporal electrode), Rugg (1984) concluded that LPC latency changes by themselves were not capable of causing significant shifts in amplitude in the region of the waveform containing the N400. Following the extended LPC latencies to nonword and nonrhyming stimuli, Rugg (1984) viewed LPC latency as an index of the "time required to evaluate and categorise a stimulus" (p. 442). Again, the crucial factor in the elicitation of the LPC appears to be the requirement for some degree of task-relevant decision-making. The harder it is to integrate a stimulus within the context (i.e. unmatched or incongruous), the longer the decision-making process and the longer the LPC latency.

3. Nonlinguistic stimuli

In a similar fashion to the LPC evoked following linguistic anomalies, a late positivity has also been recorded following nonlinguistic deviations in the priming paradigm (Stuss et al., 1986; Barrett & Rugg, 1989; 1990; Friedman, et al., 1990; Stuss et al., 1992; Paller et al., 1992). Paller et al. (1992) recorded a positivity with a centro-parietal scalp topography when subjects were required to make discriminative judgements of deviant ending melodies and suggest their failure to elicit an N400 could be attributed to its summation with the overlapping LPC to odd endings. When no judgement was required, neither the N400 nor LPC was evident, suggesting that elicitation of both the N400 and LPC required the use of active decision-related processes. Stuss et al. (1992) recorded a late positive wave in the latency range 550-650 ms following the negativity evoked by incomplete pictures, but only when the response to the picture was correct. They postulate that this waveform may reflect the subject's degree of certainty as to the identity of the object (i.e. resolution of uncertainty).

Barrett and Rugg (1989) recorded ERPs while subjects determined whether two sequentially presented faces were from the same or different occupational categories. Despite no differences in LPC amplitude between the matched and unmatched faces, longer latencies were recorded to the unmatched condition. This reiterates the Curran et al. (1993) finding of delayed LPC's following an unexpected word in a sentence paradigm.

The specificity exhibited by the two components so far discussed in this review is becoming more evident. The N400 reveals itself as a remarkably consistent index, for a range of stimulus modes, of uncertainty in which semantic expectancy and contextual constraints have been violated. The LPC, on the other hand, is revealing itself as a marker of certainty, enhanced amplitudes occurring to the resolution of uncertainty, and the closure of a sequence. The LPC has also been identified as a reliable marker of mnemonic processes, however questions relating to the particular process being indexed, and the specific stimuli characteristics which result in enhanced LPC amplitudes and greater memorability are currently unresolved.

The following section extends to the domain of ERPs and mnemonic processing. The two paradigms typically employed in the study of memory related ERP's are the recognition memory and continuous recognition tasks (CRT). The following section will review evidence suggesting an enhanced positivity (LPC) to previously encountered stimuli as compared to new stimuli (ERP repetition effect), and to initial presentations of stimuli which are later successfully recognised (in a recognition paradigm). The question regarding whether these memory-related positivities are evidence of the same underlying process will also be addressed.

ERP'S AND MNEMONIC PROCESSING

1. Recognition Memory

In a typical recognition paradigm subjects are required to choose from among the stimuli presented to determine those that have already been encoded and stored. Items processed to a deeper level during acquisition (e.g. semantic analysis) are proposed to result in greater memorability (as indexed by performance in memory tasks) than those processed to a shallow level (e.g. physical analysis; Craik & Tulving, 1975). Elaboration refers to the process of relating semantic information from the target event to other aspects of knowledge (e.g. providing a context), and the ability of that particular item to be discriminable from other items results in its degree of memorability (i.e. its distinctiveness, see Donchin & Fabiani, 1991). A congruous completion to a sentence or series of stimuli (in typical priming paradigms) is therefore thought to result in superior memory performance due to its formation of an integrated unit with its context (Neville et al., 1986). Thus, those variables considered to substantially impact on memory performance are the degree of elaboration (i.e. deep versus shallow), distinctiveness (or salience), and congruity.

Neville et al. (1986) extended behavioural investigations of retention by using the ERP as an index, tapping the dynamics of the mnemonic process. Building on the established finding that LPC's index the activity of systems associated with mnemonic functioning (Sanquist et al., 1980; Karis et al., 1984; Donchin & Fabiani, 1991), the investigation aimed to examine the interaction between congruity and recognition memory in a linguistic paradigm. ERP's were recorded in both the acquisition (sentences completed by congruous or incongruous words) and memory phase ('seen' and 'unseen' words presented in isolation).

When ERPs in the acquisition phase were analysed on the basis of subsequent recognition Neville et al. (1986) found that the correct identification of old words in the memory phase was associated with the enhancement of an LPC in acquisition. The authors consider this as evidence that "within 250 ms of the presentation of a congruous word and within 450 ms of an incongruous word, a significant portion of the brain processes which determine whether a word will or will not be recognised some time in the future have taken place" (p. 75).

Curran et al. (1993) utilised the Kutas and Hillyard (1980a) sentence paradigm followed by a recognition memory test in which the sentence stem was provided. The task did not involve the recall of the final word, subjects were required to identify which sentences had been seen in the acquisition phase. They observed that sentences which were followed by a congruous word were correctly recognised more often than those followed by an incongruous word. Also, if the LPC was enhanced to the target final word, the sentence was better remembered. The authors concluded that memory for the sentence stem itself appeared to be influenced by the "semantic resolution provided by the final word" (p. 207), semantic context constraining the encoding of new information.

In line with the above conclusions, Sanquist et al. (1980), Gunter, Jackson, and Mulder (1992), and Stelmack and Miles (1990) also have found evidence for the enhanced positivity associated with subsequent recognition. The effect has been labelled the *Dm* effect (Paller, Kutas, & Mayes, 1987; Fabiani, Karis, & Donchin , 1990) and it refers to the differences in ERP components that occur during encoding that are predictive of subsequent memory performance.

Despite such strong support for the association of the LPC with memory and the link between congruity and memory performance, mixed evidence exists for the relationship between the N400 component and mnemonic processes. Neville et al. (1986) noted the absence of the N400 to recognised incongruous words, these words generating a large N400 in the acquisition phase regardless of whether or not they were later remembered. In support of this finding, Besson et al. (1992) commented "In general, incongruous words ... elicit larger N400s than congruous words. We might then try and suppose a link between the processes reflected by the N400 and those that support subsequent memory performance. However, neither in Experiment 1 nor Experiment 2 did N400 amplitude parallel the cued-recall performance across presentations" (p. 145, Besson et al., 1992; see also Rugg, Brovedani, & Doyle, 1992).

In relation to the difference between verbal and nonverbal mnemonic processing, previous behavioural investigations have reported superior memory performance for pictures as compared to words (see Paivio, 1971; Nelson et al., 1977; and Snodgrass & Vanderwart, 1980, for reviews). Despite differences in the complexity and distinctiveness of pictures, they are still remembered with greater accuracy. When matched for size, colour, spatial distribution, and complexity, the effect remains (Nelson, Metzler, & Reed, 1974). Noldy et al. (1990) compared ERPs to pictures and words in a recognition memory paradigm and, congruent with previous results, recognition memory for pictures was found to be superior than for words (in both incidental and intentional learning conditions). In both the acquisition and memory phases, words were observed to elicit greater fronto-central and parietal negativity than pictures (N400), while pictures elicited greater parietal positivity (LPC) than words during the acquisition phase. For both words and pictures in the recognition phase, hit items elicited greater LPC amplitudes than correct rejections, further replicating the linguistic memory paradigms (e.g. Neville et al., 1986).

As the above section indicates, enhanced LPC amplitudes to stimuli subsequently recognised is a reliable phenomenon indicating that the LPC indexes some process associated with encoding. What this positivity actually reflects though is unclear, Donchin (1981) posited a 'context updating' hypothesis, whereas Neville et al. (1986) viewed it as reflecting elaborative processes (greater degrees of elaboration resulting in enhanced memory performance). Enhanced LPC amplitudes are recorded also to 'old' as compared to 'new' stimuli in the memory task implicating its role in retrieval. The following section extends the utility of the LPC as an index of mnemonic processes in the recognition paradigm to tasks involving stimuli repetition. Besson and Kutas (1993) commented that "Because the word repetition effect lies at the interface between word recognition and memory, it provides an interesting tool for studying the relationship between the cognitive operations that allow lexical identification and word retrieval" (p. 1118).

2. ERP Repetition Effect

More traditional observations of the facilitation in processing afforded an item on its second presentation are observed in tests of recognition memory in which words are classified as 'old' or 'new' (e.g. Karis, et al., 1984; Neville et al., 1986). In paradigms where the interval between the first and second presentation of an item is shorter, (such as in the CRT), the difference in ERPs to previously encountered and new words is observed to involve the modulation of not only an LPC (as evidenced above), but also an N400. This effect has come to be known as the ERP repetition effect (Rugg, 1985; 1987; 1990; Rugg, Furda, & Lorist, 1988; Bentin & Peled, 1990; Rugg et al., 1992; Besson et al., 1992; Besson & Kutas, 1993; Rugg, Doyle, & Holdstock, 1994; Bentin & McCarthy, 1994), the functional significance of which is uncertain (Otten, Rugg, & Doyle, 1993).

Rugg and colleagues suspect that the ERP repetition effect does not entirely reflect the processes of behavioural repetition priming (referring to the facilitation of performance to an item on its second presentation relative to its first). Repetition priming effects on isolated words can persist over substantial periods, whereas the ERP repetition effect appears to dissipate over less than 15 mins (Rugg, 1990). The N400 is seen to be greatly attenuated by the repetition of single words (Rugg, 1985; 1990), nonwords (Bentin & McCarthy, 1994) and the repetition of words in sentences (Besson et al., 1992; Besson & Kutas, 1993). In a similar fashion to the positivity associated with recognition paradigms, the LPC is seen to be significantly enhanced with repetition (Rugg, 1990).

Two positions have been put forward in an attempt to account for repetition effects: the abstractionist and the episodic. The abstractionists views are based largely on Morton's (1969) logogen theory of word recognition. In summary, it proposes that when a word is presented, its lexical unit (logogen) is activated. If it is still activated at the time of the second presentation of the word, the threshold of the logogen is lowered resulting in the facilitation of processing.

The episodic account posits that the mechanism underlying repetition effects is the retrieval of episodic memory traces, and is subsequently dependent on task demands, context, and modality. Repetition is hypothesised to attenuate the N400 because the availability of the decision in working memory precludes semantic access (Bentin & Peled, 1990; Bentin & McCarthy, 1994). Both interpretations assume a degree of attention is required for the effect to manifest, such an assumption finding support in the studies of Otten et al. (1993) and McCarthy and Nobre (1993).

Rugg et al. (1994) found no evidence to support the episodic account, context having no impact on ERP repetition effects. Due to the utilisation of single words as the 'local context' for the target word, it may be, as suggested by Rugg et al. (1994), that the task required minimal elaborative processing. If the stimuli had been repeated more than once or if the processing demands were increased (i.e. increased semantic association) context driven ERP repetition effects may have occurred. This reiterates Bentin and McCarthy's (1994) stance on the N400 component of the repetition effect in that "some depth of stimulus processing appears to be required" (p. 146).

Besson and Kutas (1993) in an attempt to investigate the effects of sentence context and word repetition on cued recall favoured the episodic account of the repetition effect (see also Besson et al., 1992). The authors also comment that the early portion of the *Dm* and the repetition effect are subserved by similar episodic processes, evidence for this conclusion arising out of their finding i. similar scalp distributions in the 300 -600 ms latency range, and ii. modulation of *Dm* in this latency band by various repetition conditions. The later portion of *Dm* (as evidenced in the recognition paradigm of Neville et al., 1986) however could not be equated with the repetition effect because it was observed in a latency band unaffected by repetition (i.e. 600 - 1200 ms; Besson & Kutas, 1993). The authors suggest, in a similar fashion to Neville et al. (1986), that this later portion reflects the "elaboration of the appropriate episodic memory trace for subsequent retrieval" (p. 1130, Besson & Kutas, 1993). According to Besson et al. (1992), the similarity between repetition effects and *Dm* is to be expected "insofar as recognition reflects the conscious apprehension of repeated items" (p. 146).

The similarity between the *Dm* and ERP repetition effect appears limited to the earlier latency band in which the N400 is also evident. As mentioned above, few investigators have provided evidence suggesting a role for the N400 in the memory process (see Neville et al., 1986; Besson et al., 1992; Rugg et al., 1992) and despite the study of Besson and Kutas (1993) implicating the N400 in the early portion of the *Dm* effect, the later portion was presumed to involve only the enhanced positivity associated with successful retrieval.

CONCLUSION

As the above review has indicated, investigations in the field of language comprehension have provided considerable insight into the nature of semantic processing, yet many questions remain unanswered. Much of the research to this date has been concerned primarily with the validity of utilising the ERP, particularly the N400 component, as an index of semantic processing. The N400 component, despite it appearing robust, continues to be surrounded by controversy relating to the variety of stimuli which are considered to elicit it (i.e. pictorial, linguistic, nonsemantic, auditory), and what it actually indexes (i.e. contextual integration, memory search, subject expectancy, or activation to threshold). Which of these hypotheses most accurately reflects the N400 is unresolved, most investigators tending to agree however that the N400 reflects some sort of post-access process and is dependent on a certain degree of 'depth' of processing.

Often following the N400 in priming paradigms, the LPC has been interpreted as reflecting syntactic closure (Friedman et al., 1975), integrative elaborative processing (Andrews et al., 1993) and the resolution of uncertainty (Stuss et al., 1992). Because the N400 and LPC tend to evidence themselves within a similar latency band, component overlap often results, making interpretation of the waveform particularly problematic. Typically the N400 is referred to as being 'superimposed' on the late positivity (i.e. Kutas & Hillyard, 1982; 1983; Harbin et al., 1984; Woodward et al., 1993), but depending on the theoretical perspective the investigator is aligned with, the LPC can either be a) incorporated within the semantic priming literature and perceived as separate from the N400 (Kutas & Hillyard, 1980a; 1980b; Curran et al., 1993), or b) evidence that the N400 is merely a delayed N200 (Polich, 1985a). This issue remains unresolved, further investigation, manipulating the various parameters known to influence each waveform independently, are required.

As mentioned, one area of research which has shed light on both the N400 and LPC is the investigation of repetition effects within a semantic context. Attenuated N400 and enhanced LPC amplitudes following task relevant stimulus repetition have been replicated several times (see Rugg, 1990; Besson & Kutas, 1993; Rugg et al., 1994, Bentin & McCarthy, 1994). Evidence of enhanced LPC's to stimuli later recognised (*Dm*) has resulted in questions relating to the functional similarity between the ERP repetition effect and the *Dm* .

In conclusion, both the N400 and LPC components of the ERP have contributed a great deal to current theoretical perspectives associated with semantic and mnemonic processing. The N400 is a suprisingly consistent index of subject uncertainty in paradigms manipulating semantic expectancy and contextual constraint, whereas the LPC has revealed itself as a marker of certainty and closure. What these components are specifically tapping into, and how generalisable they are to other forms of complex cognitive operations (e.g. mathematical calculation and tactile perception) is currently unknown. Following extension of the classic sentential and lexical decision paradigms to encompass other processing domains (such as pictorial and auditory) a greater understanding of the cerebral processes associated with comprehension and retrieval has been provided.

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PRIMING PICTURES AND WORDS:

AN INVESTIGATION OF THE N400 AND LPC

Journal Article

TABLES AND FIGURES

ABSTRACT

The present investigation compared ERP's produced by the processing of pictures and words in a cross modal recognition memory paradigm. In the Acquisition phase, subjects were presented with a series of sentences, one word at a time, concluded by two stimuli. The stimuli (either a word or picture) was either identical, related to the target, or unrelated. The target (word or picture) were either congruous with the sentence stem or incongruous. Subjects were divided into four groups according to the stimuli they viewed in each phase (word-word, picture-picture, word-picture, picture-word). The Memory phase involved the presentation of stimuli which were either seen in the Acquisition phase (old) or unseen (new). Results indicated firstly that the ERP waveforms to word and picture stimuli differed in both the Acquisition and Memory phases, pictures showing a striking bipolar scalp distribution (frontal negativity and parietal positivity), while words revealed a more equipotential distribution across the scalp. Throughout acquisition, both incongruous pictures and words elicited enhanced N400's, congruous pictures revealing enhanced LPC amplitudes as compared to words. The effect of the prime was evident only for incongruous targets when preceded by an identical prime, attenuating N400 amplitude. Enhanced LPC amplitudes and reduced N400 amplitudes were evident to seen stimuli throughout the memory phase as compared to unseen, especially when pictures were viewed in acquisition.

Event-related potentials (ERPs) studied in relation to language comprehension utilising linguistic stimuli have been increasingly applied to nonlinguistic stimuli. Following such investigations, comparisons can then be made between the semantic processing of words and the semantic processing of stimuli which do not necessarily access the lexicon (e.g. pictures), extending into the localisation of key areas of activity, topographical distribution, amplitude, and latency differences. Two components of the ERP have so far been identified as having particular relevance to language comprehension and mnemonic processing, the N400 and Late Positive Component (LPC). The present study follows the direction of ongoing research in this domain by directly comparing word and picture processing within a sentence priming paradigm, as well as investigating an established memory phenomenon, the picture superiority effect. The primary objective of the enquiry was to assess the current views on the processing of pictures and words using the N400 and LPC as indices, and to investigate the varying influences that semantic priming, repetition priming, and sentential context have on this process.

One line of research which has specifically explored electrophysiological responses to deviation within a semantic context has identified a negative deflection occurring approximately 400 ms after the deviant target. The classic paradigm employed to elicit the N400 was conducted by Kutas and Hillyard (1980a) and involved presenting subjects with a series of unconnected sentences which ended with either expected (e.g. "*He mailed the letter without a stamp*") or unexpected terminal words (e.g. "*He mailed the letter without a drill*"). While recording ERP's to the sentence final words, they discovered that the sentences with unexpected endings resulted in the elicitation of a negativity with a centro-parietal maximum in the 300 - 600 ms latency range (N400). Those sentences completed with expected endings however, were associated with a positivity in the same latency band.

The N400 has proven to be a robust phenomenon, readily evoked by semantic anomalies in the visual modality, most of the evidence supporting this view coming from semantic priming studies. Priming, traditionally indexed by the reaction time (RT) measure, is defined as the "facilitation given by the presentation of one item [the prime] to a response to an immediately following test item [the target]" (p. 386, Ratcliff & McKoon, 1988). More specifically, semantic priming is viewed as the facilitation of recognition of an item which has been preceded by a semantically related item. For example recognition of the target word "*pepper*" would be facilitated (i.e. responses would be faster and N400 amplitude would be attenuated) by the preceding prime word "*salt*". Conversely, if the prime "*salt*" was followed by the target "*chair*" RT would be slowed and N400 amplitude would be enhanced (relative to the expected target; Sanquist, Rohrbaugh, Syndulko, & Lindsley, 1980; Harbin, Marsh, & Harvey, 1984; Boddy, 1986; Bentin & McCarthy, 1994). The sentence paradigm adopted by Kutas and Hillyard (1980a; 1980b; 1982; 1983; 1984; 1989) described above has a similar effect on the amplitude of the N400, the preceding context biasing subject expectancies towards a particular target.

The N400 component has been shown to be sensitive to a number of variables, such as word frequency (larger N400's to low as opposed to high frequency words; see Rugg, 1990; Van Petten & Kutas, 1990), word class (larger N400's to content words as opposed to function words; see Besson, Kutas, & Van Petten, 1992), semantic relatedness (larger N400's to target words unrelated to the prime; see Kutas & Hillyard, 1989; Bentin, McCarthy, & Wood, 1985; Brown & Hagoort, 1993), a word's cloze probability (larger N400's to unexpected words within a sentence context; Kutas & Hillyard, 1984), phonological matching (larger N400's to unmatched words and nonwords; Rugg, 1984), and word repetition (larger N400's to first presentations of words; see Rugg, 1987; Besson et al., 1992).

Theoretical interpretations of the waveform include the activation hypothesis (Morton, 1969; attenuated N400's resulting from the spreading of activation throughout the semantic network to related logogens), the contextual integration view (Rugg, 1990; Holcomb, 1993; the more effort required to integrate a stimulus with the context, the greater the N400 amplitude), the semantic expectancy position (Kutas & Hillyard, 1984; N400 amplitude being inversely related to a word's expectancy within a context), and the memory search hypothesis (Stuss, Picton, Cerri, Leech, & Stethem, 1992; Bentin & McCarthy, 1994; the greater the number of possible interpretations that need to be searched, the larger the amplitude of the N400). Which of these hypotheses most accurately reflects the N400 is unresolved, most investigators tending to agree however that the N400 reflects some sort of post-lexical access, strategic process (i.e. requiring attention; see Kutas & Hillyard, 1989; Holcomb, 1993; McCarthy & Nobre, 1993; Brown & Hagoort, 1993) and is dependent on a certain degree of 'depth' of processing (Neville, Kutas, Chesney, & Smith, 1986).

Friedman, Simson, Ritter, and Rapin (1975) reported an association between the LPC and linguistic processing prior to the discovery of the N400 by Kutas & Hillyard (1980a). Enhanced positivities were recorded to sentence final words, resulting in their conclusion that the component reflected processes associated with syntactic closure. In later studies similar to the Friedman et al. (1975) investigation, sentence final inappropriate words were seen as being superimposed upon a centro-parietal positive-going shift (Kutas & Hillyard, 1982; 1983; Harbin et al., 1984; Mitchell, Andrews, Fox, Catts, Ward, and McConaghy, 1991; Andrews, Mitchell, & Ward, 1993; Woodward, Ford, & Hammett, 1993). The amplitude of the positivity in these studies was similarly interpreted as being related to syntactic closure (Kutas & Hillyard, 1982; 1983; Van Petten & Kutas, 1991), integrative elaborative processing (Andrews et al., 1993), certainty (Stuss et al., 1992), or some other aspect of completion (Roth & Boddy, 1989).

Curran, Tucker, Kutas, and Posner (1993) extended the association between the N400 and LPC, commenting that the presentation of an incongruous word in a sentence paradigm had the effect of delaying the LPC to the final word until the unexpected stimulus had been recognised. Polich's (1985a; 1985b) studies only recorded an LPC when the linguistic tasks (sentences and semantic categorisation) required subjects to make a judgement about the target word, emphasising the necessity for active, decision-making processes to be in operation.

An extensive body of research has investigated the processing differences demanded by pictures and words (Durso & Johnson, 1979; Stuss, Sarazin, Leech, & Picton, 1983; Stelmack, Plouffe, & Winogron, 1983; Vanderwart, 1984; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986; Stuss, Picton, & Cerri, 1986; Bajo, 1988; Theios & Amrhein, 1989; Noldy, Stelmack, & Campbell, 1990; Nigam, Hoffman, & Simons, 1992; Stuss et al., 1992) and overall, the literature suggests that pictures are processed differently to words, activating a semantic meaning code prior to any lexical access (i.e. accessing its name). In contrast, a name code for a verbal stimulus can be activated without any amount of prior semantic processing (Nelson, Reed, & McEvoy, 1977). In accord with this view, latency delays are consistently reported in picture naming as compared to word naming (Potter & Faulkoner, 1975).

The distinction between the mental lexicon (storing knowledge about words) and an amodal conceptual system (representing conceptual knowledge independent of modality; Nigam et al., 1992) is important in the comparison of word versus picture processing. Potter et al. (1986) suggest that both systems operate according to task demands, so in a task demanding lexical access (i.e. replacing words with pictures in sentences), pictures are processed markedly slower than words. In a conceptual task however (e.g. semantic categorisation), pictures and words are understood equally fast (Snodgrass, 1984).

A few ERP studies have conducted within-subjects comparisons of linguistic and nonlinguistic stimuli and results are mixed with regards to whether essentially the same negativity is elicited by unexpected nonlinguistic stimuli in the same manner as linguistic. Experimental comparison becomes difficult with variations in task design, task relevance, stimuli characteristics, recording procedures, and subject populations, nevertheless, it is possible to make some generalisations.

Stelmack and Miles (1990) utilised a cross-form priming paradigm in which words were preceded by pictures having the same denotative meaning (primed) or an unassociated meaning (unprimed). ERP's recorded to both the primed and unprimed words revealed that primed words elicited substantially smaller N400 amplitudes as compared to unprimed words. This finding parallels results from behavioural investigations (see Vanderwart, 1984; Potter et al., 1986; Bajo, 1988) in which response facilitation occurred to words primed by pictures, even when the relationship was abstract (Vanderwart, 1984). Stelmack and Miles (1990) did not assess the ability of words to prime pictures. By recording ERP's to words primed by either pictures or words, and to pictures primed by either words or pictures, it would have been possible to compare directly the resultant ERP components. Similar N400s in terms of amplitude, scalp distribution, and latency to unprimed words and pictures would raise the possibility that the N400 component is not merely sensitive to linguistic semantic deviance, but operates from an 'amodal' conceptual system.

Noldy et al. (1990) recorded ERP's to pictures and words in a memory paradigm and found that during the acquisition phase the N400 component was greater for words than pictures, especially in the fronto-central and parietal sites, whereas the LPC was larger for pictures than words. The negativity in both instances was interpreted as being similar to the N400 wave reported by Kutas and Hillyard (1980a), yet the differences in scalp distribution were attributed to the different verbal and physical representations of the items, requiring different processing mechanisms. The processing of pictures was perceived to require additional resources and effort as compared to the processing of words. They concluded: "Because the N450 wave clearly differentiated pictures from words, these data do not confirm the suggestion that the N400 wave is a general feature of the evaluation of any complex stimulus" (p. 424, Noldy et al., 1990; note-N450 in original text).

Stuss et al. (1983) conducted a within-subjects comparison of ERPs during naming (linguistic) and mental rotation (nonlinguistic) tasks and recorded a large negativity peaking at 400 ms which they perceived as being dependent on the amount of semantic processing required during the evaluation of any complex stimuli. The wave was considered similar to the Kutas and Hillyard (1980a) N400, yet was more frontal in scalp distribution. They considered this difference as indicating either different cerebral processes or an overlapping P300. The authors concluded however that the N400 component was evoked by stimuli requiring immediate semantic processing, commenting that " if an unexpected word must be read, an unpredictable picture named, or a semantically anomalous word processed, then an Ny or N400 is generated" (p. 143, Stuss et al., 1983).

Stuss et al. (1986) and Stuss et al. (1992), recorded ERPs to picture naming tasks, and interpreted the N400 component as a response to a signal for which access to long-term memory was required (i.e. a memory search). In contrast the LPC was viewed as a response following stimuli for which an interpretation was accessible in short-term memory. The amplitude of the

N400 was observed to vary with the number of pictures possible (the greater the number of possibilities, the larger the N400; Stuss et al., 1983), and the degree of completion of the pictures (the less complete the picture, the greater the N400; Stuss et al., 1992). In both studies the authors commented that because of the different N400 scalp distribution to picture stimuli (fronto-central) as compared to words (parieto-central) it was "difficult to determine whether the two waves represent completely different phenomena or whether they represent the same process being carried out in different regions of the brain" (p. 262, Stuss et al., 1992).

Perhaps the most positive finding for the comparison of ERP's to pictures and words in terms of the N400 component comes from the Nigam et al. (1992) study. The study was a replication of the Kutas and Hillyard (1980a) sentence paradigm, but the terminal word was replaced with a picture representing the same concept. The N400 observed to unexpected sentence final pictures was found to be identical in amplitude, scalp distribution, and latency to the negativity elicited by unexpected words. The authors took this as evidence to suggest that the N400 is an index of activity in a conceptual memory accessed by both pictures and words.

Why Nigam et al. (1992) recorded identical N400's to pictorial and word stimuli while the investigations mentioned above did not (Stuss et al., 1983; Stuss et al., 1986; Noldy et al., 1990; Stuss et al., 1992) may perhaps be due to the different paradigms employed in each instance. Nigam et al. (1992) extended the sentence paradigm of Kutas and Hillyard (1980a) to incorporate picture stimuli as targets, therefore allowing for a more direct comparison. In contrast the studies conducted by Stuss and colleagues (1983; 1986; 1992) and Noldy et al. (1990) presented pictures in a serial fashion with the task being to either memorise (Noldy et al., 1990), or name (Stuss & colleagues, 1983; 1986; 1992), the stimuli. Do these tasks demand the same depth of evaluation as the sentence paradigm (N400 elicitation appearing relatively dependent on a certain degree of 'depth' of processing; Neville et al., 1986)? Further investigation of this issue is required, and evidence of identical N400's to pictures and words in a sentence context will provide support for the Nigam et al. (1992) finding.

A direct relationship between the LPC and memory has been proposed, and it has been shown that during the acquisition phase of a recognition memory task, words that were subsequently recognised elicited late positivities with enhanced amplitudes (Sanquist et al., 1980; Neville, Kutas, Chesney, & Smith, 1986; Stelmack & Miles, 1990; Gunter, Jackson, & Mulder, 1992). Subsequent to such findings, the LPC is hypothesised to index some process associated with encoding and the "elaboration of the appropriate episodic memory trace for subsequent retrieval" (p. 1130, Besson & Kutas, 1993).

Similarly, an enhanced positivity is recorded following presentation of 'old' (seen) as compared to 'new' (unseen) stimuli during a recognition task (Neville et al., 1986; Noldy et al., 1990), supporting the view that the LPC indexes some process involved in retrieval. Enhanced LPC amplitudes are also recorded following stimulus repetition (Rugg, 1985; 1987; 1990; Rugg, Doyle, & Holdstock, 1994) and this has resulted in investigators aligning the mechanisms involved in the memory task with those associated with stimulus repetition (Besson & Kutas, 1993). However no consistent link has been found between the N400 component and subsequent memory. Incongruous words have been observed to generate a large N400 in the acquisition phase whether or not they are recognised subsequently (Neville et al., 1986; Besson et al., 1992; Rugg, Brovedani, & Doyle, 1992).

Following evidence of different processing mechanisms involved in the evaluation of picture and word stimuli, behavioural and ERP research to this date suggests that as a result of these processing differences, pictures tend to result in superior memory performance as compared to words

(Paivio, 1971; Nelson, Metzler, & Reed, 1974; Noldy, et al., 1990). If the proposed association between memory and the LPC is correct, then pictures should elicit substantially greater LPC's than words during acquisition.

Noldy et al. (1990), compared the ERPs elicited by pictures and words in a memory paradigm. Congruous with previous behavioural studies, recognition memory for pictures was found to be superior than for words (in both incidental and intentional learning conditions). Pictures were also observed to elicit greater parietal positivity (LPC) than words in the acquisition phase, in both the intentional and incidental learning conditions. For both words and pictures in the recognition phase, hit items (seen) elicited greater amplitude LPC's than correct rejections (unseen), mirroring results obtained in linguistic memory paradigms (e.g. of Neville et al., 1986).

The aim of this study is to compare directly the processing of pictures and words in a sentence paradigm and a subsequent recognition memory task. The target stimuli (either words or pictures) in the acquisition phase will be preceded by both a biasing sentential context and a prime which varies in its relationship to the target. The purpose of utilising both a sentence stem and prime stimulus (which is either identical, semantically associated, or unrelated to the target) is to investigate the varying influences of the different primes on the N400 component typically observed to unexpected sentence completions. By directing the subjects attention to the congruity of the target stimulus with the sentence context, it will then be possible to clarify which manipulation (sentence congruity, repetition, or semantic association) has the greatest impact on N400 amplitude.

The primary objectives therefore, are firstly to replicate the Nigam et al. (1990) finding of equivalent N400's to both pictures and words in a sentence context, secondly, to investigate the varying effects of priming manipulations on ERPs to target stimuli, and thirdly, to assess the consequent effects of utilising either pictures or words in a sentence paradigm in a within- and cross-modal recognition memory task.

METHOD

SUBJECTS

Fifty-four subjects, aged between 17 and 30 years, were chosen from a pool of students in an introductory psychology course, all received course credit for their participation. Selection was based on responses to a medical questionnaire, ensuring that subjects were healthy individuals with no history of drug/alcohol abuse, no family history of alcoholism, no psychiatric or neurological disease or uncorrected visual impairment (see Appendix A).

STIMULI

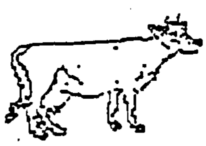
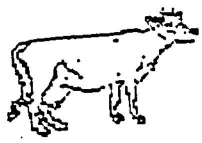
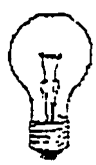
Acquisition

Stimuli consisted of 35 sentence stems, a majority of which were derived from Bloom and Fichsler (1980), the others were self generated. Each sentence stem had 6 completions, resulting in a total of 210 sentences. Sentences were concluded either by a prime and a target word (see Table 1) or a prime and a target picture (see Table 2) of comparable size. The targets were either congruous (C) or incongruous (I) with the preceding sentence context, whereas the primes were divided into three levels: identical to the target (I), related to the target (R) , or unrelated to the target (U). Subsequently, each sentence could be classified according to the congruity of the target word with the sentence and the association between the target and the prime (see Figure 1). Congruous sentences were therefore labelled as identical congruous (IC), related congruous (RC), or unrelated congruous (UC), and similarly the incongruous sentences labelled identical incongruous (II), related incongruous (RI), and unrelated incongruous (UI).

TABLE 1: **Example of different prime and target variations for each sentence stem in the Word group.**

Sentence Type	Sentence Stem	Prime Stimulus	Target Stimulus
Identical Congruous (IC)	The farmer milked his	cow	cow.
Related Congruous (RC)	The farmer milked his	goat	cow.
Unrelated Congruous (UC)	The farmer milked his	candle	cow.
Identical Incongruous (II)	The farmer milked his	candle	candle.
Related Incongruous (RI)	The farmer milked his	globe	candle.
Unrelated Incongruous (UI)	The farmer milked his	doll	candle.

TABLE 2: **An example of an identical congruous (IC) and a related incongruous (RI) sentence for the Picture group (pictures and words were approximately the same size).**

Sentence Stem	Prime	Target
The farmer milked his		
The farmer milked his		

Sentences varied between 5 and 9 words in length and were chosen for the high degree of constraint they imposed on subsequent words (Bloom & Fichsler, 1980). An independent rating conducted prior to experimentation (n = 10; Appendix B1) revealed an average cloze probability of .98 for the congruous target word. Target words concluding each sentence were also independently rated (n = 10) on a scale from 1 (totally unexpected ending) to 5 (totally expected ending, see Appendix B2). Incongruous sentence completions were consistently judged to have an average rating of 1.7 (range 1-3) while congruous completions averaged a rating of 4.1 (range 3-5). Associations between the target and the prime were also judged by a group of independent raters (n=10) according to the degree of association between them on a scale of 1 (no relation) - 5 (highly related, see Appendix B3). Related targets and primes were judged to have an average rating of 4.5 (range = 3-5), while unrelated target and primes averaged a rating of 1.4 (range = 1-3). The picture stimuli were derived from Snodgrass and Vanderwart (1980) and were chosen according to the concept required by the targets and primes (average % name agree of pictures = 90.5%, Snodgrass & Vanderwart, 1980).

Memory

In the Memory phase of the experiment, subjects either viewed pictures or words. Fifty percent of the subjects were presented with the same stimuli in both the acquisition and memory phases (25%: Acquisition: *word* - Memory: *word*; 25%: Acquisition: *picture* - Memory: *picture*), 50% being presented with different stimuli (25%: Acquisition: *word* - Memory: *picture*; 25%: Acquisition: *picture* - Memory: *word*).

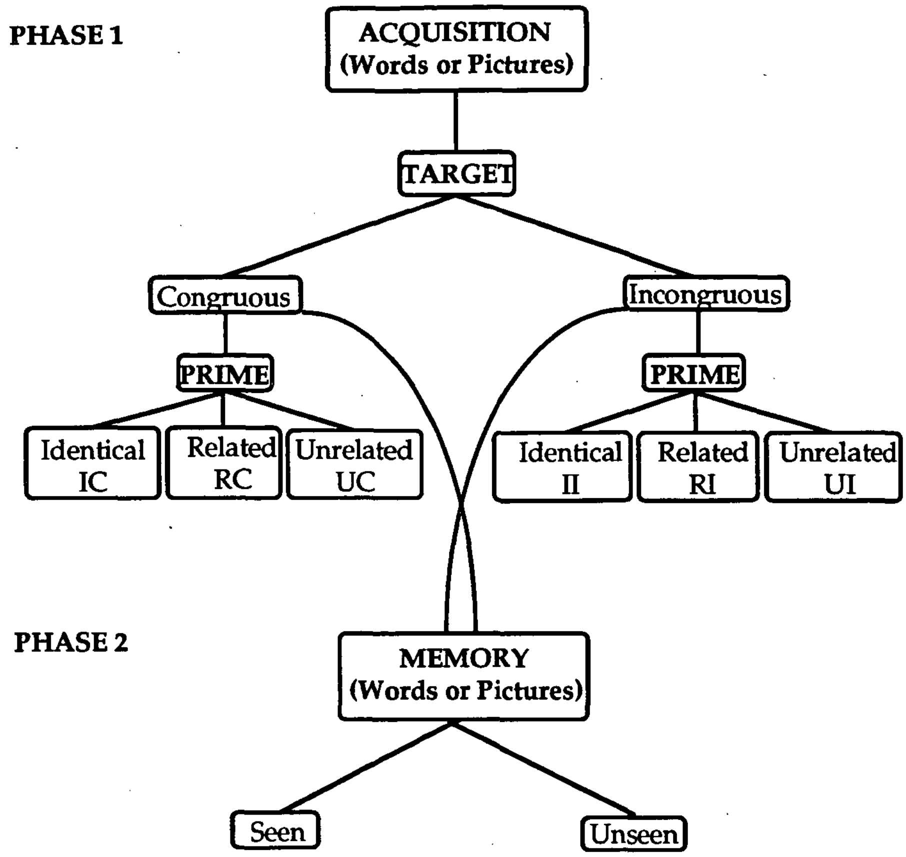


FIGURE 1: The design employed in the Experiment consisted of two phases: the Acquisition Phase and the Memory phase. Stimuli for the Acquisition Phase consisted of sentence stems concluded by a target word or picture which was either congruous or incongruous with the sentence. Prime stimuli preceded each target and were either identical, related or unrelated to the target. Stimuli employed in the Memory phase were either words or pictures and consisted of the congruous and incongruous targets (seen) and new stimuli (unseen).

Stimuli for the recognition memory task were derived from the target stimuli in the Acquisition phase (congruous and incongruous words or pictures) and these were matched, according to word length and word frequency (where possible), with nouns from the Kucera and Francis (1967) noun list to make up the unseen (new) stimuli (see Table 3). Seventy seen stimuli and thirty-five unseen stimuli made up a total of 105 stimuli in the memory task.

TABLE 3. **Kucera and Francis (k-f: 1967) means and standard deviations for target words (SEEN) and new words (UNSEEN) employed in the Memory phase.**

WORD LENGTH	n - SEEN	n - UNSEEN	k-f - SEEN	k-f - UNSEEN
3	11	5	mean = 69.9 s = 79.6	mean = 67 s = 53.5
4	16	8	mean = 47.3 s = 42.8	mean = 44 s = 23.8
5	19	10	mean = 60.8 s = 133.07	mean = 50.2 s = 71.9
6	7	8	mean = 41.6 s = 82.7	mean = 23 s = 27.9
7	3	2	mean = 15 s = 19.3	mean = 17.5 s = 16.3
8	1	1	mean = 2	mean = 3
9	3	1	mean = 4.67 s = 5.5	mean = 0
TOTAL	70	35	**mean = 34.5**	**mean = 29.24**

DESIGN

The study was divided into two phases: Acquisition and Memory. In the Acquisition phase, there was one between subjects factor (stimulus mode: pictures/words), and three within-subjects factors (stimulus position: prime/target; sentence: congruous/incongruous; and prime type: identical/related/unrelated). In the Memory phase there was one between subjects factor (stimulus mode: pictures/words) and one within subjects factor (memory: seen/unseen). The relationships between these variables were depicted in Figure 1.

Prior to experimentation, subjects were randomly allocated to each group labelled according to the stimuli they received in the Acquisition and Memory phases respectively (Word Word [ww], Word Picture [wp], Picture Word [pw], and Picture Picture [pp]).

ERP DATA COLLECTION

Scalp electrical activity was recorded using tin electrodes mounted on an elastic electrode skull cap, referenced to the right ear. Recordings were taken from frontal ground (FP_Z, Gratton, Coles, & Donchin, 1983), midline sites F_Z, C_Z, P_Z, and lateral sites P_3, P_4, in accordance with the International 10/20 system (Jasper, 1958). N400 typically has been found in previous ERP language studies to be maximal at C_Z and P_Z using a sentence paradigm (Kutas & Hillyard, 1980a; Curran et al., 1993) whereas LPC has been found to be maximal at P_Z (Karis et al., 1984). The horizontal electroculogram (H-EOG) was recorded from tin electrodes placed on the outer canthus of each eye to record horizontal eyemovements. The vertical electroculogram (V-EOG) was recorded from electrodes placed on the supraorbital and infraorbital ridges of the right eye to record vertical eyemovements. Electrode impedance did not exceed 10 kOhms.

A Grass Model 12 Neurodata Acquisition System was used for the electroencephalographic (EEG) recordings. The high frequency cut off for both EOG and EEG recordings was 30 Hz, while the low frequency cut off was .01 Hz. For the Acquisition phase, recordings were digitised at a rate of 250 Hz for a 2000 ms epoch commencing 100 ms prior to the onset of the prime stimulus. For the Memory phase, recordings (only collected to the hits and correct rejections) were digitised at 500 Hz for a 1000 ms epoch, commencing 100 ms prior to stimulus onset. Experimental manipulations and data collection were controlled by an IBM compatible 486 computer system linked to an IBM compatible 386 AT which presented the stimuli. Single trial data was recorded and averaged online for each subject for each stimulus condition and electrode site. Trials where eye movements exceeded 70 μV were rejected online.

PROCEDURE

Following random allocation to an experimental group (ww, wp, pp, pw), subjects were seated in a dimly lit, sound attenuated room facing a video monitor located 1 m away. The recording and control apparatus were located in an adjacent room. Following presentation of instructions, in which subjects were told to focus their attention on the target-sentence relationship rather than the prime-sentence or prime-target relationship (see Appendix C), the Experimenter withdrew to the adjacent room and subjects were presented with two blocks of 105 sentences (Block A - sentences IC, UC, RI; Block B - sentences RC, II, UI; the order of presentation being counterbalanced across subjects). A five minute rest-break intervened between the two blocks. Sentences were presented one word at a time and concluded with a period (.). The centre of the screen contained an eye-fixation spot which remained visible between stimuli, assisting subjects in minimising eye movements. Stimuli were presented for a duration of 300 ms, 700 ms separating the offset of one stimulus and the onset of the next. ERP recordings were to the final two stimuli of each sentence (2 s epoch).

The Acquisition phase lasted for a duration of 30 minutes, following which subjects were provided with another 5 minute rest-break in which the instructions for the memory task were given, informing them of the necessity to make speeded decisions as to the familiarity of the stimuli being presented (see Appendix C). Subjects were then presented with a series of 105 stimuli, one at time, to which they were to respond (button push) if they recognised the stimuli from the preceding phase. An eye fixation spot was visible in the centre of the screen between stimuli, assisting in minimising eye movements. Stimuli were presented for a duration of 300 ms with an interstimulus interval of 3 seconds, allowing for a response to be made. Reaction Times (RTs) were collected provided a response was made within 2 s. A warning tone sounded 250 ms prior to the onset of the next stimulus to orient subjects to the imminent presentation.

Following completion of the memory phase (duration = 5 mins), subjects were led from the experimental room, electrodes were removed, and they were debriefed. The study was granted ethical approval by the University of Tasmania Ethics Committee.

DATA ANALYSIS

Before analysis of the Acquisition phase, twelve subjects were excluded due to excessive eye movement (a minimum of 25 trials being required in each prime condition). A further six were excluded from the analysis of the Memory phase due to either excessive eye movement or a failure to reach a criterion of responding (a minimum of 30 responses being required to seen, and 25 to unseen stimuli). Data from a total of 42 subjects were included in the Acquisition phase analysis (22 subjects viewing words and 20 viewing pictures), and data from a total of 36 subjects in the Memory phase analysis (18 subjects viewing pictures and 18 viewing words).

For the Acquisition phase data, grand mean averages were computed for responses from each stimuli mode (words or pictures), for each stimuli position (prime or target), for each prime type (identical, related, and unrelated), for each sentence (congruous and incongruous), and for each electrode site (F_z, C_z, P_z, P_3, P_4). For Memory phase data, grandmean averages were computed for responses for each subject group (ww, pw, pp, wp), for each memory stimuli type (seen or unseen) and for each electrode site (F_Z, C_Z, P_Z, P_3, P_4).

Data was scored using a base to peak measure within predefined windows and the timing of these peaks was used for latency scores. N400 was defined, following inspection of the grandmean averages, as the largest negativity in the latency range 250-500 ms and the LPC was defined as the largest positivity following N400 in the latency range 550 - 800 ms (Van Petten & Kutas, 1991). ERP data for each subject were averaged and then sorted on the basis of experimental condition. To test for differences in amplitude and latency of the N400 and LPC across conditions and subject groups, mixed design analyses of variance (ANOVAs) were used to evaluate the effect of the independent variables. Between groups ANOVA's were also conducted on RT data collected during the memory phase. Greenhouse Geisser corrections were applied to ANOVA where applicable. Newman Keuls (NKs) tested the differences between the individual means and a rejection region of .05 was used throughout.

RESULTS

ERP ANALYSIS

Acquisition Phase

a. Grandmean Averages

Prime Position

Grandmean averages computed for word primes revealed the greatest effect of congruity (i.e. enhanced negativity to incongruous as compared to congruous stimuli in the latency range encompassed by the N400 component, see Figure 2) at the site C_Z and a lesser effect at F_Z, P_Z, P_3, P_4, whereas for picture primes, a congruity effect was most evident at F_Z. For words, this difference was most apparent in the related condition (Figure 2,

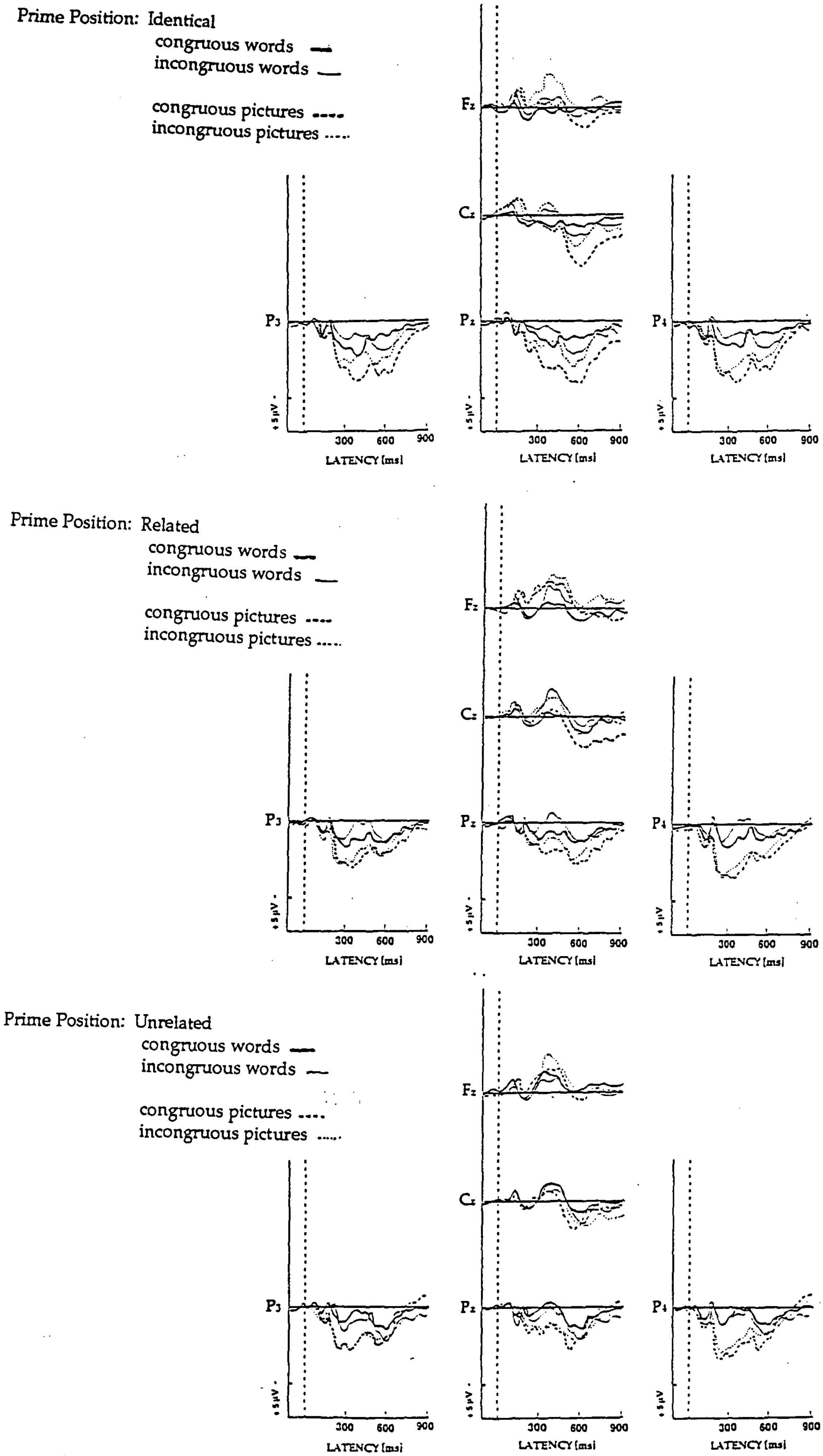


Figure 2: Grandmean Averages for Acquisition phase, Prime Position.

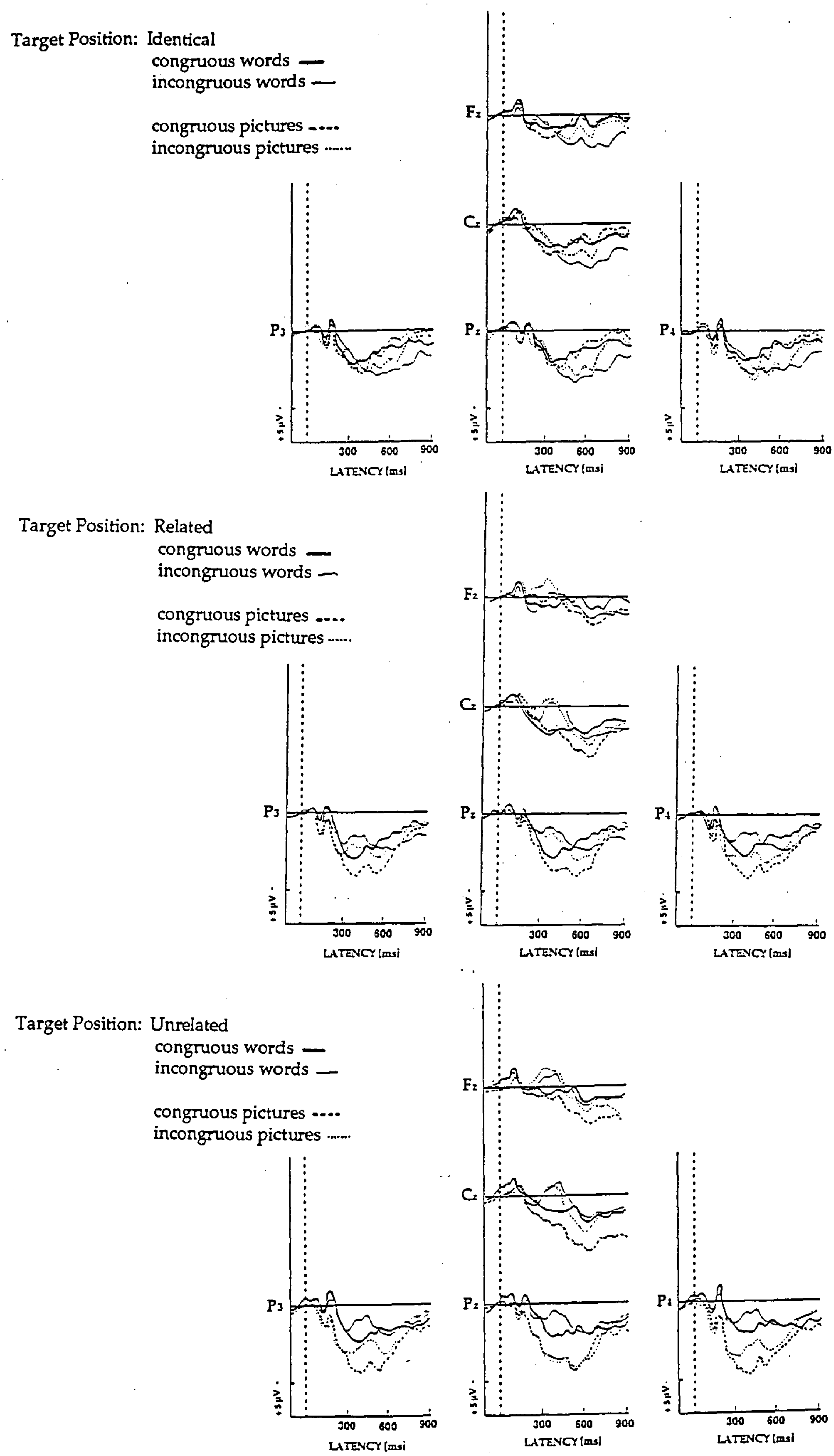


Figure 3. Grandmean Averages for Acquisition phase, Target Position.

middle), while for pictures the congruity effect was enhanced in the identical condition (Figure 2, top), where incongruous pictures evoked greater amplitude negativity than incongruous words.

For word stimuli a little post-N400 positivity, peaking at approximately 5 - 10 μV and maximal for at Pz for unrelated primes (Figure 2, bottom), was present in the LPC latency range, returning to baseline at approximately 700 - 800 ms. Late positive activity to pictures appeared maximal for congruous stimuli (IC) at all sites (especially P_z), amplitudes being greater (10 - 15 μV) and peaking a little earlier than to word primes (approximately 550 -600 ms). The positivity to pictures was most apparent where N400-like activity was less discernable.

Target Position

For word and picture targets, grandmean averages revealed a congruity effect most evident following related (Figure 3, middle) and unrelated (Figure 3, bottom) primes . This was most evident at C_z, P_z, P_3, and P_4 for word stimuli, and at F_z, and C_z for picture stimuli. This suggests firstly, that the related prime was not strong enough to attenuate the negativity to the incongruous target, and/or secondly the unrelated prime was not strong enough to increase the negativity to the congruous target. Sentential congruity therefore appeared to override the prime-target association. For word and picture targets following identical primes (Figure 3, top), no effect of congruity was evident at any site, the waveform taking the form of an N2-P3 complex at P_z. The repetition of the congruous/incongruous word following a sentence therefore appeared to attenuate the negativity in the N400 latency range, repetition overriding incongruity with the sentence context.

For both picture and word targets, there was evidence of increased positivity over the central and parietal regions. Overall, the LPC was enhanced to congruous pictures following related and unrelated primes at parietal sites.

b. Statistical Analysis

A 5-way mixed design analysis of variance (ANOVA: 2x2x2x3x5) was completed on the amplitude and latency data of the N400 and LPC, with a between groups factor of stimulus mode (words or pictures), and within groups factors of stimulus position (prime or target), sentence (congruous or incongruous), prime type (identical, related, or unrelated) and site (F_Z, C_Z, P_Z, P_3, P_4). The following sections will detail the main effects and interactions from the analysis relating to each factor for each component.

N400 COMPONENT

Means tables, ANOVA results and Figures for N400 Amplitude and Latency data are presented in Appendices D, E, and F.

- **Words v's Pictures (Stimulus mode)**

i. N400 Amplitude

No main effect of stimulus mode was evident in the 5-way mixed design ANOVA for N400 amplitude, however, following a significant stimulus mode x site interaction ($F(4, 160) = 12.15$, $p < .001$, $\varepsilon = .51$) it was apparent that overall, words elicited greater amplitude negativity than pictures at parietal sites, and pictures evoked greater amplitude negativity than words at F_Z (NKs). Picture stimuli revealed a striking bipolar scalp distribution with enhanced frontal negativity and parietal positivity whereas word stimuli resulted in a more even distribution across the scalp.

The significant stimulus mode x stimulus position x site interaction ($F(4,160) = 10.1$, $p < .001$, $\varepsilon = .36$) revealed that at F_Z, the enhanced negativity to pictures was the result of effects occurring at the prime position, no difference was evident between pictures and words at the target position (NKs). At parietal sites however, both prime and target words evoked greater amplitude negativity than pictures, the difference enhanced at the prime position (NKs). Observation of the grandmean waveforms (Figure's 2 and 3) indicates that this effect is the result of the enhanced positivity to the congruous picture stimuli.

An effect of prime type was most evident for word stimuli as compared to picture stimuli at F_Z and C_Z and P_Z (stimulus mode x prime type x site: $F(8,320) = 3.57, p < .05, \varepsilon = .24$) where identical primes elicited smallest amplitude negativity and unrelated primes maximal amplitude negativity (NKs). For picture stimuli, no difference between related and unrelated primes was observed at F_Z and C_Z, while at parietal sites identical, related and unrelated primes were all equivalent, evoking significantly smaller amplitude negativity than words (NKs).

ii. N400 Latency

Following the 5-way mixed design ANOVA conducted on N400 latency data, little evidence existed to differentiate pictures and words according to N400 latency results.

- **Prime Type (I, R, U)**

i. N400 Amplitude

A main effect of prime type was revealed in the 5-way mixed design ANOVA in which identical primes were observed to evoke significantly smaller amplitude negativity than related and unrelated primes in the N400 latency range ($F(2,80) = 12.24$ $p < .001$, $\varepsilon = .89$), especially at F_Z and C_Z (prime type x site interaction: $F(8,320) = 15.3, p < .001, \varepsilon = .24$).

In assessing the effect of the various prime types on the congruous and incongruous targets, the stimulus position x sentence x prime type interaction was observed to approach significance ($F(2,80) = 7.11$, $p = .05$, $\varepsilon = .49$). At the target position (see Figure 4), an identical prime preceding an incongruous target had the effect of significantly reducing N400 amplitude as compared to related and unrelated primes to the extent that incongruous completions were equivalent in magnitude to congruous completions (NKs). Repetition, therefore, appeared to have a greater impact on negativity than semantic association. No impact of prime type was evident for congruous completions (NKs), suggesting that the congruity of the target stimulus with the sentence context outweighed the nature of the prime (see also grandmean waveforms, Figure 3).

ii. N400 Latency

For N400 latency data, the 5-way ANOVA also revealed a significant main effect of prime ($F(2,80) = 7.13$, $p < .001$, $\varepsilon = .94$) indicating longer latency N400s following related and unrelated primes as compared to identical primes (NKs).

- **Prime v's Target (Stimulus position)**

i. N400 Amplitude

The main effect of stimulus position reached significance in the 5-way ANOVA and revealed that prime stimuli evoked greater amplitude N400s than target stimuli ($F(1,40) = 50.37$, $p < .001$), especially at F_z and C_z (stimulus position x site: $F(4,160) = 12.1$, $p < .01$, $\varepsilon = .36$; and NKs).

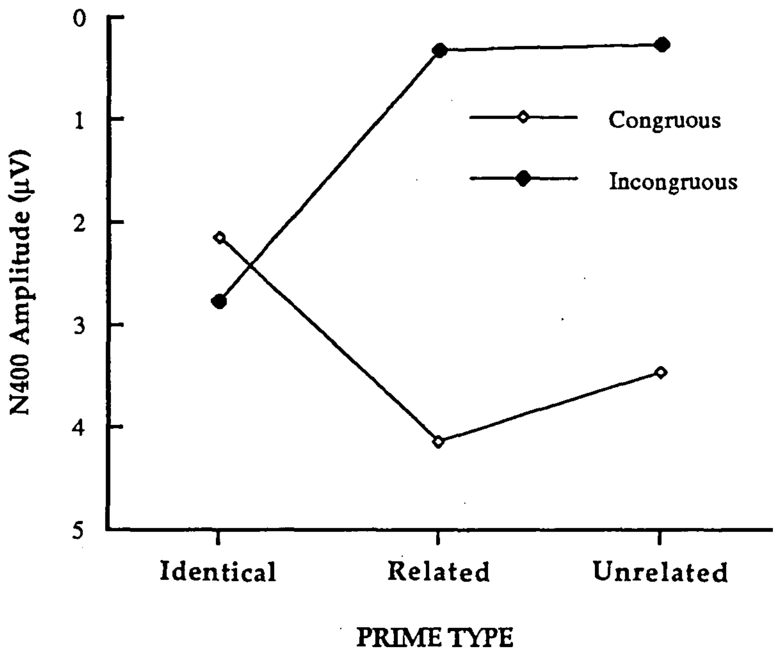


Figure 4: Effect of Prime Type on Congruous and Incongruous Sentences for N400 Amplitude data at Target Position.

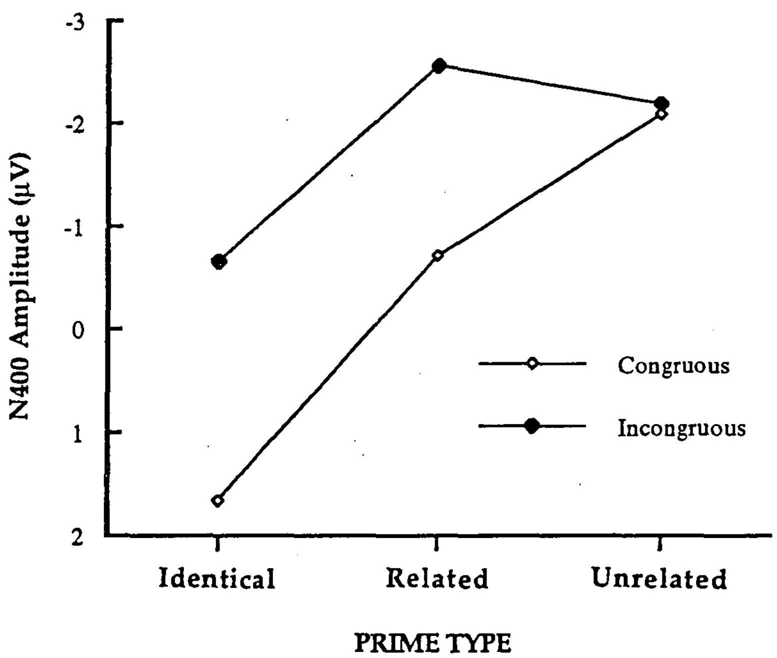


Figure 5: Effect of Prime Type on Congruous and Incongruous Sentences for N400 Amplitude data at the Prime Position.

ii. N400 Latency

As is evident from the significant main effect of stimulus position for N400 latency, target stimuli were observed to evoke shorter latency N400s than prime stimuli ($F(1,40) = 6.46$, $p < .05$).

• **Congruity (Sentence)**

i. N400 Amplitude

The 5-way mixed design ANOVA revealed a significant main effect of sentence in which incongruous stimuli elicited greater amplitude negativity than congruous ($F(1,40) = 33.89$, $p < .001$) especially at C_Z (sentence x site: $F(4,160) = 5.75$, $p < .05$, $\varepsilon = .32$; and NKs). The stimulus mode x sentence x site interaction approached significance ($F(4,160) = 3.7$, $p = .05$, $\varepsilon = .32$) and indicated that the effect was evident for both words and pictures across all sites, yet was enhanced for pictures at C_Z (NKs).

The clearest picture of an effect of congruity on N400 amplitude was visible at the prime position following the stimulus position x sentence x prime type interaction which approached significance ($F(2,80) = 7.11$, $p = .05$ $\varepsilon = .49$; see Figure 5). No effect of prime type was evident when the prime was incongruous (NKs) however best completion (IC) primes were observed to elicit significantly reduced negativity as compared to related (RC) and unrelated (UC) primes (NKs).

ii. N400 Latency

No significant effects of congruity for N400 latency data were evident in the 5-way mixed design ANOVA.

LATE POSITIVE COMPONENT

Means tables, ANOVA results and Figures for LPC Amplitude and Latency data are presented in Appendices D, E, and F.

- **Words v's Pictures (Stimulus mode)**

i. LPC Amplitude

The 5-way mixed design ANOVA was applied to the LPC amplitude data and revealed no significant main effect of stimulus mode, yet the significant stimulus mode x sentence interaction ($F(1,40) = 7.4, p < .01$; see Figure 6) revealed greater amplitude LPC's to congruous pictures as compared to congruous words (NKs). No such effect was evident for incongruous stimuli.

ii. LPC Latency

No significant main effect of stimulus mode was evident in the 5-way ANOVA for LPC latency data.

- **Prime Type (I, R, U)**

i. LPC Amplitude

The significant stimulus position x prime type interaction conducted on LPC amplitude data ($F(2,80) = 6.42, p < .01, \varepsilon = .58$) revealed greater amplitude positivities to target stimuli preceded by related and unrelated primes as compared to identical primes (NKs), evident only for picture stimuli (stimulus mode x stimulus position x prime type: $F(2,80) = 5.09, p < .05, \varepsilon = .58$). The effect of prime on LPC amplitude manifested at central and parietal sites (stimulus position x prime x site: $F(8,320) = 3.63, p < .05, \varepsilon = .2$; and NKs).

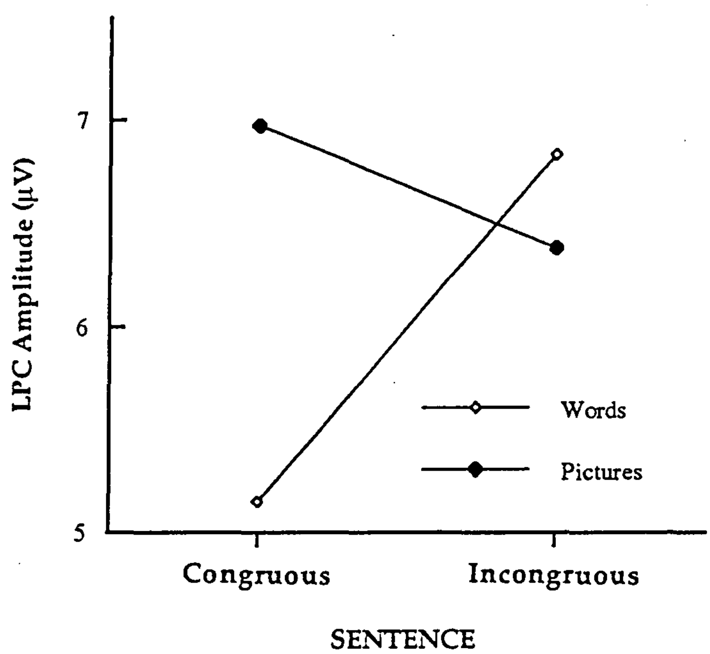


Figure 6: Effect of Sentence Congruity on Word and Picture Stimuli in the Acquisition Phase for LPC Amplitude data.

ii. LPC Latency

No significant main effect of prime type was evident for LPC latency data, yet the stimulus position x prime type interaction ($F(2,80) = 5.43$, $p < .05$, $\varepsilon = .71$) indicated longer latency LPC's to targets preceded by identical primes as compared to related and unrelated primes (NKs).

- **Prime v's Target stimuli (Stimulus position)**

i. LPC Amplitude

The 5-way mixed design ANOVA conducted on LPC amplitude data revealed a significant main effect of stimulus position ($F(1,40) = 18.73$, $p < .001$) in which maximal amplitude LPC's were recorded to target stimuli especially when the sentences ended incongruously (stimulus position x sentence: ($F(1,40) = 5.74$, $p < .05$; and NKs) and when they followed related and unrelated primes (stimulus position x prime type: $F(2,80) = 6.42$, $p <.05$, $\varepsilon = .58$; and NKs).

- **Congruity (Sentence)**

i. LPC Amplitude

Incongruous targets evoked greater amplitude positivity than congruous ($F(1,40) = 5.74$, $p < .05$), especially at parietal sites (sentence x site: $F(4,160) = 8.43$, $p < .01$, $\varepsilon = .37$; and NKs).

ii. LPC Latency

Congruous sentences were observed to elicit longer latency LPC's than incongruous (main effect of sentence: $F(1,40) = 5.95$, $p < .05$). However, following the significant sentence x prime type x site interaction $F(8,320) = 4.09$, $p < .01$, $\varepsilon = .43$) it was evident that congruous stimuli only elicited longer Latencies than incongruous at P_z when the prime was unrelated to the target (NKs).

Recognition Memory Phase

a. Grandmean Averages

Grandmean averages were computed for responses from each group (ww, pw, pp, wp), for each stimulus type (seen, unseen), and for each electrode site (F_Z, C_Z, P_Z, P_3, P_4). for the Memory phase of the study (Figure 7)

Across all groups, maximal amplitude negativity was apparent at F_Z and C_Z, unseen stimuli typically eliciting greater amplitude negativity than seen. For pp and pw groups (Figure 7, top), enhanced positivity in the LPC latency range was observed at central and parietal sites, especially to seen stimuli. LPC amplitude peaked approximately 100 ms later for the pw group (650 ms) as compared to the pp group (550 ms). The enhanced LPC to seen stimuli was less evident for the ww group, and almost nonexistent for the wp group (Figure 7, bottom).

b. Statistical Analysis - Memory phase

For the Memory phase a 4-way mixed design analysis of variance (ANOVA: 2x2x2x5) was completed on the amplitude and latency data of the N400 and LPC, with two between groups factors of memory stimuli mode (Mstim: words/pictures) and acquisition stimuli mode (Astim: words/pictures), and within groups factors of stimulus type (seen/unseen) and site (F_Z, C_Z, P_Z, P_3, P_4). The aim of this analysis was firstly, to determine the impact of the acquisition stimulus mode (words v's pictures) on the subsequent ERPs in the memory phase, and secondly, to assess the difference in ERPs to stimuli which had been seen in the acquisition phase as compared to unseen stimuli.

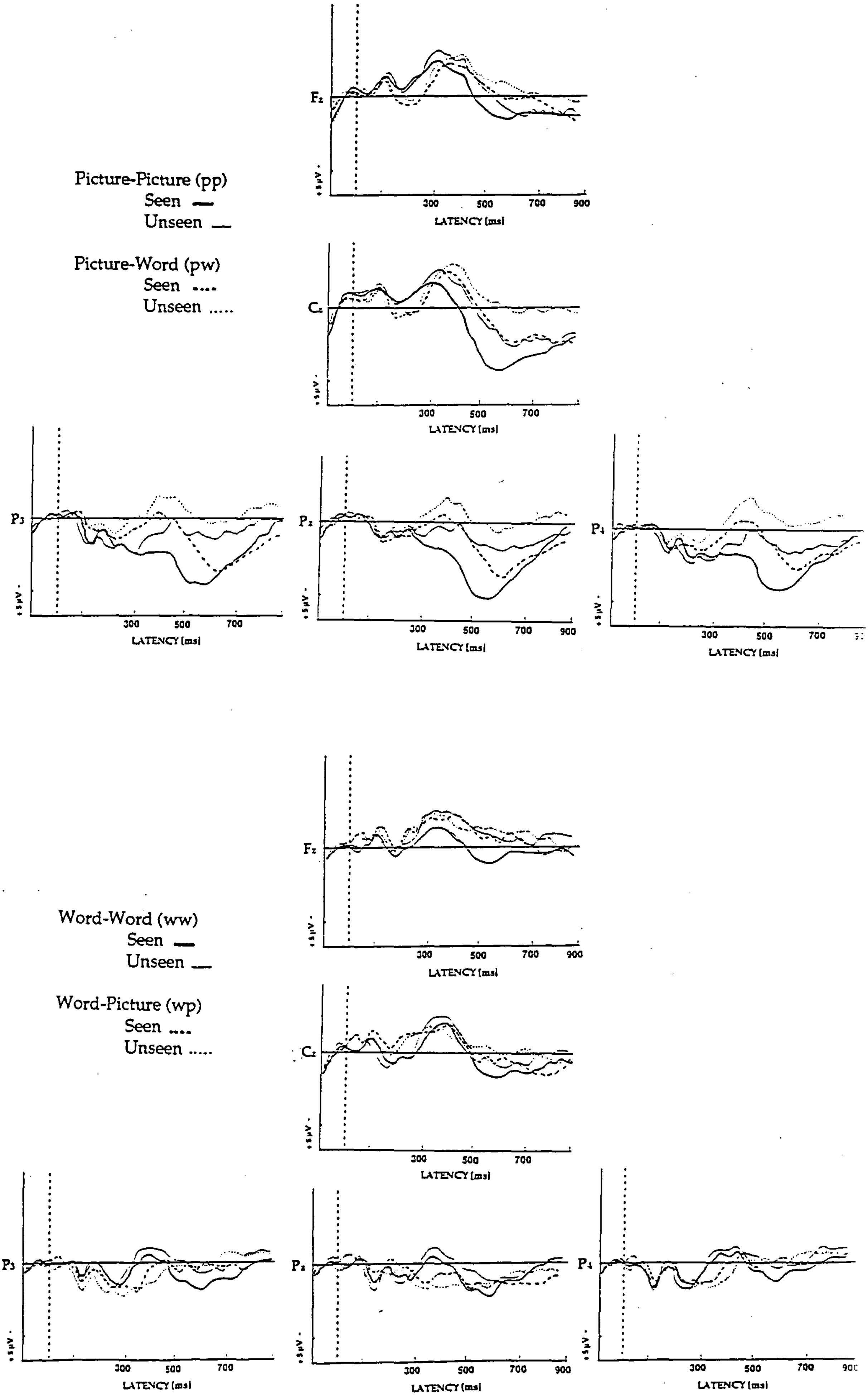


Figure 7. Grandmean Averages for Memory phase.

N400 Component

Means tables, ANOVA results and Figures for N400 Amplitude and Latency data are presented in Appendices D, E, and F.

i. N400 Amplitude

The 4-way ANOVA completed on the N400 amplitude data revealed maximal N400 amplitudes occurring at F_Z and Cz ($F(4,144) = 28.83$, $p < .001$, $\varepsilon = .46$) to both words and pictures (Mstim x site: $F(4,144) = 5.26$, $p = .00$, $\varepsilon = .46$, $p < .01$; and NKs). Unseen stimuli typically elicited greater amplitude negativity than seen stimuli (main effect of stimulus type: $F(1,36) = 6.7$, $p < .05$) especially when pictures were viewed throughout the Acquisition phase (pp, pw) in comparison to words (ww, wp: Astim x memory: $F(1,36) = 4.85$, $p < .05$; and NKs).

ii. N400 Latency

For N400 latency data, no significant main effect of stimulus type was evident, however the Astim x stimulus type interaction was significant ($F(1,36) = 12.26$, $p < .001$) and revealed longer latency N400s to unseen stimuli as compared to seen stimuli if subjects viewed pictures in the acquisition phase (NKs). Seen stimuli elicited longer latency N400s when words were viewed in the acquisition phase as compared to pictures (NKs). This pattern was most evident at parietal sites (Astim x stimulus type x site: $F(4,144) = 3.4$, $p < .05$, $\varepsilon = .69$, and NKs).

LATE POSITIVE COMPONENT

Means tables, ANOVA results and Figures for LPC Amplitude and Latency data are presented in Appendices D, E, and F.

i. LPC Amplitude

Following the 4-way ANOVA conducted on LPC amplitude data, the significant main effect of stimulus type ($F(1,36) = 18.74, p < .001$) revealed that seen stimuli elicited greater amplitude LPC's than unseen. This was apparent at P_z (memory x site: $F(4,144) = 8.68, p < .01, \varepsilon = .32$; and NKs). Subjects who viewed pictures in the Acquisition phase (i.e. pp, pw) elicited greater amplitude LPC's to stimuli in the Memory phase than those who viewed words (i.e. ww, wp; main effect of Astim: $F(1,36) = 4.85, p <.05$; and NKs), especially when the stimuli were seen as compared to unseen (Astim x stimulus type interaction: $F(1,36) = 4.67, p = .04$, and NKs; see Figure 8). This effect was most evident at central and parietal sites (Astim x stimulus type x site: $F(4,144) = 7.22, p<.01, \varepsilon = .32$; and NKs). Because there was no evidence of a significant effect of memory stimulus mode (Mstim), it appears that viewing pictures in the acquisition phase determined the LPC amplitude to stimuli in the memory phase.

ii. LPC Latency

The 4-way ANOVA revealed a significant interaction between Astim and Mstim for LPC latency data ($F(1,36) = 9.14, p < .01$, see Figure 9). Reduced LPC latencies were recorded to picture stimuli when pictures were viewed in the Acquisition phase (pp) as compared to words (wp, NKs). In contrast, if subjects viewed words in the Acquisition phase, LPC latency was equivalent whether they saw words (ww) or pictures (pw) in the Memory phase (NKs).

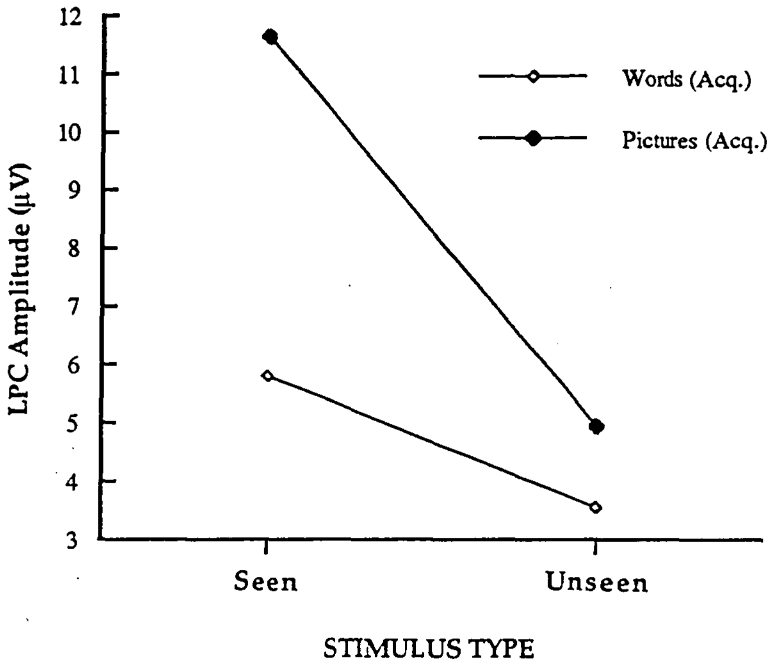


Figure 8: Effect of Acquisition Stimulus Mode on Seen and Unseen stimuli in the Memory Phase for LPC Amplitude.

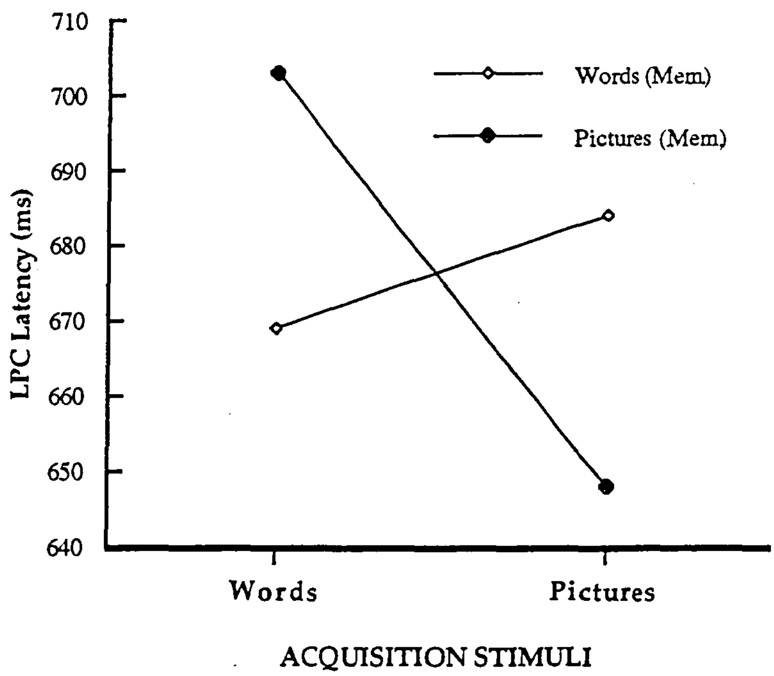


Figure 9: Interaction between Acquisition stimulus mode and Memory stimulus mode for LPC Latency.

The Astim x stimulus type interaction also reached significance ($F(1,36) = 4.9$, $p < .05$) and similarly to LPC amplitude, only pictures (pp, pw) resulted in a differentiation between memory stimuli, shorter latencies occurring to seen as compared to unseen stimuli (NKs).

Reaction Time (RT) Analysis

To parallel the analysis conducted on ERPs recorded during the memory phase, the RT data collected during the memory task was analysed with a 3-way mixed design ANOVA (2x2x2) with between groups factors of memory stimuli (Mstim: words or pictures) and acquisition stimuli (Astim: words or pictures) and a within groups factor of stimulus type (seen or unseen). Two-way mixed design ANOVAs (2x2) were then computed for false alarms (FA), correct rejections (CR), misses and hits, using the between subjects factors of Mstim and Astim. Means tables and ANOVA results for the RT data are presented in Appendices D E, and F.

For RT, a significant main effect for Astim was evident in the 3-way ANOVA ($F(1,36) = 13.28$, $p < .001$) revealing shorter RTs to memory stimuli when pictures were viewed in the acquisition phase (responses approximately 200 ms faster, see Figure 10). Faster RTs were also exhibited by subjects in the pp group as compared to the wp group (Astim x Mstim interaction: $F(1,36) = 7.31$, $p < .01$, and NKs), paralleling the LPC latency data (Figure 9).

The 2-way ANOVAs conducted on FA, CR, hits and misses revealed no significant main effects or interactions. A trend was evident however, ($F(1,36) = 3.27$, $p = .05$) for more FAs to occur when subjects viewed different stimuli in the acquisition and memory phases (i.e. pw and wp). For the hit data, a main effect of Astim approached significance ($F(1,36) = 3.36$, $p = .05$)

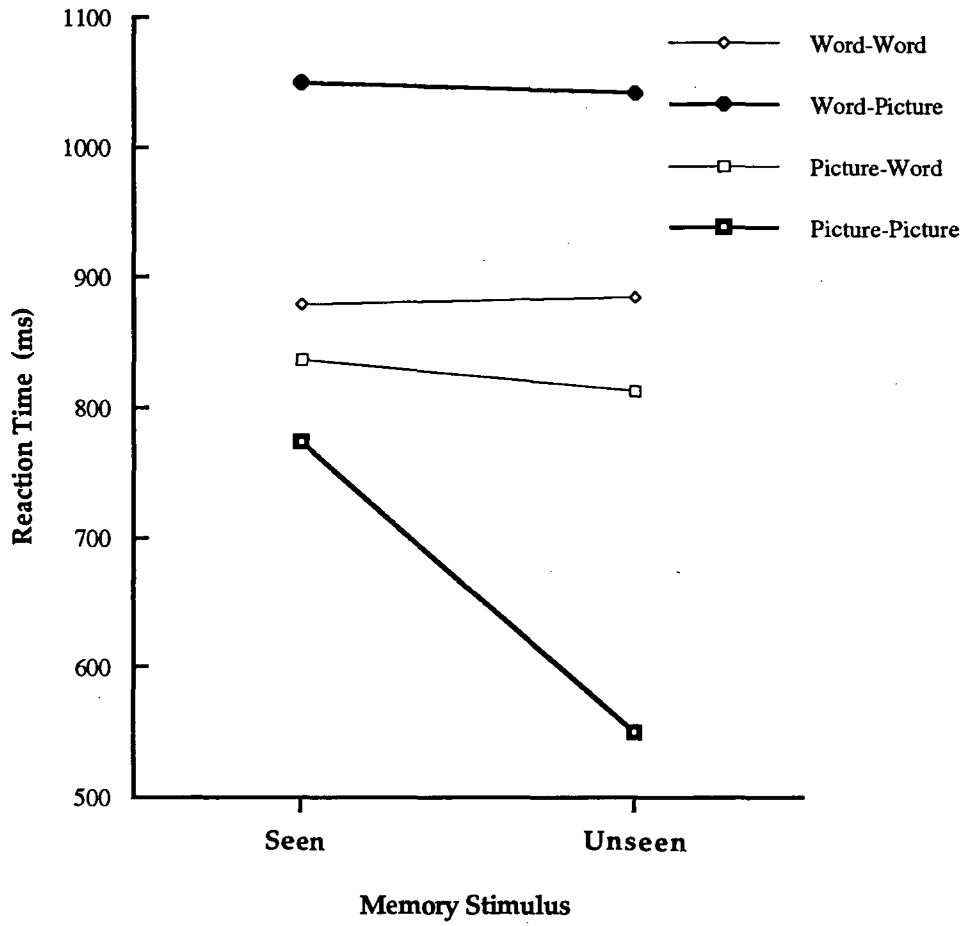


Figure 10: Reaction Time mean data for Seen and Unseen stimuli in each subject group.

in which subjects responded with more hits when they viewed pictures in the acquisition phase.

DISCUSSION

The present investigation compared the LPC and N400 components of the ERP produced by the processing of pictures and words in a memory paradigm. Prime and target stimuli (words or pictures) were viewed in the Acquisition phase, while either words or pictures were viewed in the subsequent Memory phase. Following analysis of the Acquisition phase, it was evident that incongruous picture and word stimuli elicited enhanced N400 amplitudes as compared to congruous stimuli, especially at Cz. N400 amplitude was also observed to be attenuated to best completion primes (IC) as compared to related (RC) and unrelated primes (UC).

Comparing the ERPs elicited by primes and targets, prime stimuli were observed to evoke greater amplitude N400s with longer latencies than target stimuli overall, negativities typically maximal at the frontal site for pictures and frontal, central and parietal sites for words. Maximal amplitude LPC's were recorded at P_z to incongruous target stimuli as compared to prime stimuli, especially when they followed related and unrelated primes.

ERPs to picture stimuli revealed a striking bipolar scalp distribution, enhanced negativity at frontal sites and greater positivity in parietal sites, especially at the prime position, in comparison to words. Word stimuli tended not to show such a distinct variation across the scalp, tending to elicit more negative ERPs over the parietal sites at both the prime and target positions. Target words and pictures appeared to elicit similar amplitude negativity at F_z and C_z, congruous pictures evoking significantly enhanced LPC's as compared to words at parietal sites (Figure 3).

Looking at the impact of prime type on the target, it was apparent that the effect of sentence congruity on N400 amplitude was outweighed by repetition, only when the target was incongruous. The identical prime attenuated the amplitude and shortened the latency of the N400 to the incongruous target to the extent that no difference existed between congruous and incongruous targets. In contrast, the related and unrelated prime appeared to have no impact on the incongruous target, nor was any effect of prime evident on the congruous targets, sentence congruity in these instances overriding the effects of prime.

Turning to the ERPs associated with the Memory phase, results indicated firstly that greater amplitude LPC's were recorded to congruous pictures in the acquisition phase compared to words. The analysis conducted on the memory data revealed that seen stimuli elicited greater amplitude positivities with shorter latencies than unseen, this effect was most evident at C_z and Pz, and when pictures were viewed in the Acquisition phase (i.e. groups pw and pp, see Figure 7, top). Paralleling the ERP findings, RT responses were typically faster (approximately 200 ms faster), and more accurate (nonsignificant trend), when pictures were viewed in the acquisition phase as compared to words. The lack of a significant effect of memory stimuli mode suggests that viewing pictures in the acquisition phase determined the LPC amplitude to both word and picture memory stimuli.

No differences between words and pictures were observed in the memory phase with regards to N400 amplitude, both revealing maximal negativity at Fz and Cz. Unseen stimuli tended to elicit greater amplitude and longer latency N400s than seen when pictures were viewed in the acquisition phase (pp, pw) as compared to words (ww, wp).

In relation to the first objective of the study, the replication of the Nigam et al. (1990) finding of equivalent N400s to both pictures and words in a sentence context, the current study does not wholly support their conclusions. Nigam et al. (1992) noted that sentences concluded by words and pictures were observed to elicit identical N400s with regards to the centro-parietal scalp distribution, amplitude, and latency, emphasising the similarity between their results and the original Kutas and Hillyard (1980a) finding. The present investigation recorded similar N400s at the central site to both pictures and words, yet instead of having a centro-parietal maximum for the N400 component, pictures revealed a fronto-central distribution. Both the current study and the Nigam et al. (1990) investigation found that words tended to elicit more negative ERPs overall and both words and pictures elicited substantial N400s to anomalous sentence completions. Perhaps explaining the scalp distribution differences evident between the studies, Nigam et al. (1992) did not record from the frontal site, which is where picture stimuli in the present study revealed maximal negativity.

Most investigations utilising pictorial stimuli have recorded more frontal N400s (Stuss et al., 1986; Friedman, Sutton, Putnam, Brown, & Erlenmeyer-Kimling, 1988; Barrett, Rugg, & Perrett, 1988; Noldy et al., 1990; Stuss et al., 1992). Stuss et al. (1983) suggested that this difference in scalp distribution may "indicate that negative waves at this latency may reflect different cerebral processes" (p. 144), while Noldy et al. (1990) attributed the differences in picture and word ERPs to the different verbal and physical representations of the items (i.e. essentially the same phenomena occurring at different locations; see also Stuss et al., 1992). Based on the present findings, this latter interpretation appears most viable, the N400 waveform to pictures appearing identical to words in all respects except for its scalp distribution. Barrett and Rugg (1990) extend this view with evidence of unprimed picture stimuli modulating two ERP components, one frontally distributed (N300) and the other more widely distributed (N400). The earlier N300 was seen as being specific to the processing of pictures, while the N400 was perceived as being identical to that seen in word processing. The current study shows no evidence of this earlier frontal negativity specific to pictures however.

The second question posed prior to the investigation referred to the relationship between the prime stimuli (identical, related and unrelated) and their effects on both the congruous and incongruous targets. Repetition priming was shown to have an effect only on the ERP to the incongruous target (smaller amplitudes and shorter latency). Attenuation of the N400 component following stimulus repetition is a well documented finding (Rugg, 1985; 1987; 1990; Bentin & Peled, 1990; Rugg et al., 1992; McCarthy & Nobre, 1993; Rugg et al., 1994; Bentin & McCarthy, 1994). The reason for the current finding of no attenuation of the N400 to the congruous targets can be explained by referring to a proposed interaction between repetition and semantic congruity, both appearing to converge to influence a common stage of processing (Besson et al., 1992). Besson et al. (1992) found evidence to suggest that repetition of sentences reduced the amplitude and shortened the latency of the N400 component more for incongruous than congruous words. Morton's (1969) logogen model of word recognition has typically been employed to explain the locus of these effects, suggesting that both sentence congruity and repetition act to change activity within the logogen (representing each word in the lexicon). Once the threshold for recognition has been attained (i.e. by a 'priming context' - through presentation of an identical word, a related word or a biasing sentence context), less activation is required (either due to a reduced threshold or an increased resting level) to enable the word to be recognised faster. This account however does not hypothesise an interaction between semantic and repetition priming effects. The episodic account of repetition effects posits however, that the mechanism underlying repetition effects is the retrieval of episodic memory traces, and is subsequently dependent on task demands, context, and modality (see Bentin & Peled, 1990; Besson & Kutas, 1993: Bentin & McCarthy, 1994).

Rugg (1985; 1987) also found evidence for attenuated N400's following presentation of an identical stimulus and a related stimulus. The author maintained that despite this resemblance, distinct cognitive processors are engaged, pointing to differences in amplitude (larger for repetition), scalp distribution (more equipotential across the scalp for repetition), and latency (earlier onset for repetition) of the N400. Besson et al. (1992) suggest that the differences between these interpretations may stem from the different paradigms utilised (single word contexts versus sentence contexts). The issue is not resolved, recent studies by Rugg and colleagues (e.g. Rugg et al., 1994) utilising word pairs found no support for the interaction between repetition and semantic context. Besson and Kutas (1993) however, in support of the episodic memory account, concluded that "linguistic context has a large influence on word repetition priming" (p. 1127) following an investigation of repetition effects within a sentence paradigm.

Evidence of enhanced N400s to incongruous targets as compared to congruous targets following related and unrelated primes suggests firstly that the paradigm employed in the current study was effective in its ability to elicit the N400 component to incongruent target stimuli. Mitchell et al. (1991) also found evidence of enhanced N400 amplitudes to incongruous and nonidentical sentence completions when sentence stems were concluded by two words presented simultaneously (one above the other). Secondly, it suggests that sentence congruity had a greater influence on the ERP waveform than prime association. The latter finding was suprising as the N400 is consistently reported to be attenuated following semantically related primes (Sanquist et al., 1980; Harbin et al., 1984; Bentin et al., 1985; McCarthy & Nobre, 1993; Brown & Hagoort, 1993). The semantic priming effect is generally considered to require active attention (Holcomb, 1993; Brown &

Hagoort, 1993; McCarthy & Nobre, 1993; Chwilla, Hagoort, & Brown, 1994), and in the current study subjects were instructed to focus on the match between the target and the sentence rather than the target and prime. This may have resulted in the greater influence of sentence congruity on N400 amplitude as compared to the prime relationship.

The LPC is typically observed to be enhanced following stimulus repetition (Rugg, 1985; 1987; 1990; Besson et al., 1992; Rugg, et al., 1994; Bentin & McCarthy, 1994), yet in the present study shorter latencies and smaller amplitude LPC's were apparent following repetition as compared to semantically associated (related) and unrelated primes. Across a variety of studies however, the behaviour of the LPC appears to be variable. Besson et al. (1992) found that the direction of the amplitude change was dependent on congruity, incongruous sentence completions showing greater amplitude positivity than congruous. The present study also recorded maximal LPC's to incongruous target stimuli especially following related and unrelated primes. Perhaps in this instance sentence congruity has a greater impact on LPC amplitude than repetition (in contrast to the N400 component which reveals an opposite trend). The impact of utilising picture stimuli (which typically elicited enhanced LPC amplitudes as compared to words) may also have complicated the interpretation of the effects. Besson et al. (1992) comment that following such a variety of results in which the LPC reveals sensitivity to a large number of variables, the LPC repetition effect requires further study.

The third objective of the study involved investigating the ERP's involved with the correct recognition of picture and word stimuli following the Acquisition phase. Picture superiority in memory paradigms is a well recognised phenomenon (see Paivio, 1971; Nelson et al., 1977; Snodgrass & Vanderwart, 1980). The present results revealed evidence of this superiority and are in accordance with the Noldy et al. (1990) findings of enhanced

LPC's to pictures during acquisition, enhanced LPC's to seen (hit) stimuli as compared to unseen and superior recognition memory for pictures as compared to words (see also Neville et al., 1986). The greater LPC amplitudes for pictures than words during acquisition is consistent with the association of enhanced LPC's with better memory. This evidence is inferred rather than direct however, a better method being to compare the ERP waves to items that were subsequently remembered (i.e. Neville et al., 1986).

The ERP differences exhibited by pictures and words in both the Acquisition and Memory phases of the experiment (i.e. the enhanced LPC amplitudes to pictures; the greater N400 negativity to words; and word stimuli eliciting a more equipotential distribution across the scalp as compared to pictures) is also congruent with the Noldy et al. (1990) results, suggesting that "To the extent that these ERP waves reflect differences in the cognitive processing of pictures and words, the effects are common to both encoding and retrieval" (p. 426; Noldy et al., 1990).

For both ERP and behavioural indices, nonsignificant trends indicated that shorter [LPC and RT] latencies occurred when the same stimuli were viewed in both the Acquisition and Memory phases, suggesting that subjects experienced this task as easier. The lack of a distinct LPC to seen picture stimuli in the wp group may reflect the poor ability of word traces layed down during acquisition (represented in the lexicon) to transfer to a more semantic/conceptual representation (where pictures are believed to be represented, Potter & Faulkoner, 1975; Potter et al., 1986; Noldy et al., 1990; Nigam et al., 1992) in order to facilitate recognition to picture stimuli in the Memory phase. In contrast, evidence of substantial LPC's to seen word stimuli in the pw group (see grandmean waveform at Pz, Figure 7) suggests that picture stimuli observed in acquisition are more able to transfer from a conceptual representation to the lexical representation of the same concept.

Mixed evidence has been found regarding a link between the N400 and memory performance. Investigations suggesting no link include Neville et al. (1986), Besson et al. (1992), Rugg et al. (1992), and Gunter et al. (1992) while Woodward et al. (1993) and Besson and Kutas (1993) found evidence to support a relationship between N400 and recall. Those studies finding no evidence of a link between N400 and memory tended to utilise either a recognition memory task (Neville et al., 1986; Rugg et al., 1992; Gunter et al., 1992) or a cued recall task (Besson et al., 1992). Woodward et al. (1993) however used a written recognition test in which subjects were cued with a sentence fragment and provided with a choice of four alternatives (two congruent and two incongruent words. They found evidence to suggest that the N400 difference waveform amplitudes were "highly correlated with recognition memory" (p. 318, Woodward et al., 1993), allowing them to conclude that the "N4 difference amplitude reflects the subjects' ability to adopt strategies to aid memory" (p. 318). The fact that the N400 amplitude difference waveform (which collapses the ERP's to typical and atypical stimuli) 'correlated' with memory does not imply causation however. Besson and Kutas (1993) also utilised a cued-recall task to investigate the ERP indices of memory processes and found evidence to suggest that "N400 amplitude is not only correlated with repetition but also with subsequent recall" (p. 1126). One factor which may have contributed to the discrepancies between these results may involve the stimuli used. Besson and Kutas (1993) utilised low cloze probability sentence final words in contrast to other studies which typically employed both incongruous and congruous completions (i.e. Neville et al., 1986). It also appears that a crucial factor separating these positive and negative instances of N400 amplitude in relation to memory functioning is the method employed. Cued recall tasks often result in a correlation between N400 amplitude and memory, whereas recognition tasks show no evidence of this relationship.

In the present investigation, reduced amplitude and shorter latency N400s were recorded to seen stimuli as compared to unseen and this effect was maximal at F_z and C_z, especially when pictures were viewed during acquisition. Because no comparison was made between memory for congruous and incongruous stimuli however, it is not possible to comment on the relationship between the N400 and subsequent memory performance. The N400 observed during the memory phase is most likely indexing the recognition of seen stimuli, attenuated amplitudes occurring as the result of repetition.

In summary, contrasting with the Nigam et al. (1992) conclusion, the present study found evidence to suggest differences in the ERP waves between words and pictures in both the Acquisition and Memory phases of the study. Pictures revealed a different scalp distribution than words in the N400 latency band (greater negativity at the frontal sites and enhanced positivity at parietal sites) and greater amplitude positivities in the LPC latency band. Both words and pictures displayed enhanced N400 amplitudes to incongruous stimuli however, suggesting either that the ERP waveforms represent the same process being carried out in different regions of the brain or that they index totally different mechanisms of comprehension. Evidence appears to be mounting, however, to suggest that the N400 can be elicited by unprimed linguistic and nonlinguistic stimuli.

Depending on the congruity of the target stimulus, the effect of the prime tended to vary with regards to the impact it had on the N400 component. Incongruous targets revealed a sensitivity to repetition while congruous targets did not. The episodic account was referred to in an explanation of this result (Besson & Kutas, 1993), whereas the lack of an impact of prime association (i.e. related and unrelated) on the ERP to the target appeared to be the result of task demands, biasing subject attention towards the target-sentence relationship rather than the target-prime relationship. Further investigation in which subject attention is manipulated either by instruction or by utilising a masking procedure, may clarify the effects observed in the current experiment.

The enhancement of the LPC component typically observed following stimulus repetition (Rugg, 1985) was not evident in the present study, research in this field providing different interpretations as to its the functional significance (Besson et al., 1992). The complexity of the present design and the utilisation of both picture and word stimuli makes an explanation of this finding difficult. Positive results were found for the picture superiority effect with regards to LPC amplitude and RT facilitation however. In a similar fashion to Noldy et al. (1990), enhanced LPC amplitudes were recorded to pictures during acquisition as compared to words. Seen (hit) stimuli also resulted in enhanced LPC amplitudes in comparison to unseen, especially when pictures were viewed throughout the acquisition phase.

These findings therefore support the view firstly, that pictures are processed differently to words, both capable however, of eliciting the N400 component; secondly, only incongruous target stimuli revealed an effect of prime, repetition priming overriding sentence congruity; and finally the enhancement of LPC amplitude to picture stimuli in the acquisition phase and seen stimuli in the memory phase reinforced both the association of the LPC with mnemonic processing, and the picture superiority effect.

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APPENDICES

APPENDIX A:

MEDICAL QUESTIONNAIRE

University of Tasmania
Department of Psychology

Medical History Questionnaire

NAME..

AGE...PHONE...

Do you; A. Smoke Cigarettes.................................. Yes ☐ No ☐

B. Use or have experimented with either drugs or marijuana ....Yes ☐ No ☐

Have you recently lost a lot of weight ?........................ Yes ☐ No ☐

Have you ever had any operations ?............................ Yes ☐ No ☐

Have you ever been a patient in a Mental hospital?......... Yes ☐ No ☐

Have you ever been a patient in any other hospital ?......... Yes ☐ No ☐

HAVE YOU EVER HAD OR ARE YOU NOW SUFFERING FROM ANY OF TH FOLLOWING;

Tumour, Growth, Cyst, Cancer..............Yes ☐ No ☐

Paralysis (Including Polio).................. Yes ☐ No ☐

Shortness of Breath......................... Yes ☐ No ☐

Palpitations or Pounding Heart........... Yes ☐ No ☐

High or Low Blood Pressure............... Yes ☐ No ☐

Heart Disease................................... Yes ☐ No ☐

Severe Reactions to Drugs or Injections... Yes ☐ No ☐

Frequent Colds or Nasal Obstructions... Yes ☐ No ☐

Troat troubles.................................. Yes ☐ No ☐

Fainting Attacks................................ Yes ☐ No ☐

Fits or Convulsions.......................... Yes ☐ No ☐

Epilepsy..	Yes ☐	No ☐
Giddiness..	Yes ☐	No ☐
Severe Headache..................................	Yes ☐	No ☐
Migraines..	Yes ☐	No ☐
Nervous Trouble..................................	Yes ☐	No ☐
Severe Depression..................................	Yes ☐	No ☐
Mental Illness..	Yes ☐	No ☐
Attempted Suicide..................................	Yes ☐	No ☐
Frequent Indigestion..............................	Yes ☐	No ☐
Heartburn..	Yes ☐	No ☐
Ulcer of the Stomach..............................	Yes ☐	No ☐
Ulcer of the Duodenum..........................	Yes ☐	No ☐
Gall Bladder Trouble..........................	Yes ☐	No ☐
Gall Stones..	Yes ☐	No ☐
Vomiting Blood..................................	Yes ☐	No ☐
Passing Blood Through the Bowels......	Yes ☐	No ☐
Sugar Diabetes..................................	Yes ☐	No ☐
Concussion..	Yes ☐	No ☐
Severe Head injury..............................	Yes ☐	No ☐
Loss of Consciousness..........................	Yes ☐	No ☐
Any other Illness or Disability...............	Yes ☐	No ☐

HAVE ANY OF YOUR IMMEDIATE FAMILY OR PEOPLE LIVING WITH YOU;

Been a Heavy Drinker..............................	Yes ☐	No ☐
Had Fits..	Yes ☐	No ☐
Had Epilepsy..	Yes ☐	No ☐
Had Nervous Illness..............................	Yes ☐	No ☐
Had Mental Illness..................................	Yes ☐	No ☐

CURRENT MEDICATION

Are you taking any medications at present ? ...... Yes ☐ No ☐
If YES, which Drugs are you taking?

....

....

VISION

Do you wear spectacles?...................... Yes ☐ No ☐

Are you Colour Blind?......................... Yes ☐ No ☐

Indicate your visual Defect ....

....

If able, indicate below the exact visual conditions that apply to you;

DISTANT VISION		COLOUR VISION
UNAIDED	CORRECTED TO	
RIGHT 6/	6/	RIGHT:
LEFT 6/	6/	LEFT:

AMSLER FULL FIELD
AMSLER CHART

HEARING

Have you any hearing difficulties? ...... Yes ☐ No ☐
If YES, indicate hearing defects ....

....

DRINKING HISTORY

On how many days last week did you drink alcohol ?...
- None ☐
- One or Two days ☐
- Five or Six Days ☐
- Every Day ☐

Do you usually drink...
- Never ☐
- During the Week ☐
- Friday Night ☐
- Week Ends Only ☐

When you drink is it Normally.................................
- Light Beer ☐
- Beer or Cider ☐
- Wine ☐
- Mixed spirits ☐
- Straight Spirits ☐

On a day when you drink, how many drinks would you usually have?

- One or Two ☐
- Three to Five ☐
- Five to Eight ☐
- Eight to Twelve ☐
- More than Twelve ☐

How long have you been drinking at this level ?............

- Weeks ☐
- Months ☐
- Years ☐

Do you get drunk?..

- Never ☐
- Rarely ☐
- Once a Month ☐
- Once a Week ☐
- More Frequently ☐

Does your father get drunk?......................................

- Never ☐
- Rarely ☐
- Once a Month ☐
- Once a Week ☐
- More Frequently ☐

Does your Mother get drunk?....................................

- Never ☐
- Rarely ☐
- Once a Month ☐
- Once a Week ☐
- More Frequently ☐

Do you have any relatives whom you would consider to be alcoholic?

Yes ☐ No ☐

If YES, How many and what relationship are they to you? ....

....

....

OTHER INFORMATION

ow often do you smoke Cigarettes ?.................. Never ☐

Less than 10 per day ☐

10 to 20 per day ☐

20 to 40 per day ☐

Over 40 per day ☐

do you Drive Regularly ? Yes ☐ No ☐

YES, for how many years have you done so ? ....

....

have you ever been involved in a serious road traffic accident ?

Yes ☐ No ☐

YES, did you sustain any head injuries ? Yes ☐ No ☐

Note:

This is a formal requirement of the Ethics Committee of the University of Tasmania that the information provided on this questionnaire be held under security to comply with confidentiality regulations and to protect your privacy. You can be assured that information will be available only to the principal researcher and not to any other party. The questionnaire will be destroyed following the completion of the project.

Thankyou for your assistance,

APPENDIX B 1

SENTENCE COMPLETION TASK

Below you will see a list of sentences which are missing the final word. For each sentence, write down the **word** which you think **best completes** the sentence.

---

1. My mother knitted me a
2. The cowboy fired the
3. The hairdresser cut the man's
4. John swept the floor with a
5. She wore her socks and
6. The children held hands and formed a
7. To get to work, I drive my
8. While skiing, Jan broke her
9. Most people eat with a knife and
10. He placed the ring on her
11. Lucy put the flowers in the
12. At the circus you can see the silly
13. The farmer milked his
14. While walking in the orchard, Tim picked one
15. Some sports use a bat and a
16. Don't place all your eggs in the one
17. Windy days are great for flying a
18. Carol sang and played her acoustic
19. Tony put a saddle on his
20. She wore a beautiful diamond
21. My eyes water when I slice an
22. The Time-keeper glanced at his
23. Most people live in a
24. The bartender poured the beer into a
25. To keep the dogs out of the yard he put up a
26. Tom hit a bump and fell off his
27. To see in the cave we shone a
28. Spot the dog slept outside in his
29. To keep my trousers up I use a
30. He loosened the tie around his
31. The boat passed easily under the
32. The kids fed the duck some stale
33. Julie fell down and skinned her
34. She tied up her hair with a yellow
35. He hung his coat up on the

APPENDIX B 2

SENTENCE RATING TASK

On the following pages there are 180 sentences which end either in a way that **makes sense** (i.e. the final word is expected), or in a way that **doesn't make sense** (i.e. the final word is unexpected).

Your task is to <u>read each sentence</u> and to **rate** the final word on a scale from **1 - 5** (see below) as to **how expected** the final word is.

Rate the **final word** on the following scale:

1	3	5
Unexpected ending		Expected ending

1. Tom hit a bump and fell off his sled.
2. The hairdresser cut the man's bus.
3. She wore her socks and chicken.
4. He hung his coat up on the rocket.
5. Don't place all your eggs in the one basket.
6. The Time-keeper glanced at his dress.
7. Carol sang and played her acoustic moon.
8. Most people live in a house.
9. Julie fell down and skinned her elbow.
10. The bartender poured the beer into a glass.
11. Most wine is made from grapes.
12. To keep the dogs out or the yard he put up a wall.
13. Carol sang and played her acoustic nose.
14. He placed the ring on her thumb.
15. Lucy put the flowers in the accordion.
16. Some sports use a bat and a telephone.
17. She wore a beautiful diamond screw.
18. To get to work, I drive my motorcycle.
19. To keep the dogs out of the yard he put up a picture.
20. To keep my trousers up I use a belt.
21. My eyes water when I slice an orange.
22. Don't place all your eggs in the one barrel.
23. The cowboy fired the cannon.
24. He loosened the tie around his waist.
25. The children held hands and formed a circle.
26. To see in the cave we shone a pig.
27. To get to work, I drive my car.
28. The Time-keeper glanced at his watch.
29. My mother knitted me a church.
30. He placed the ring on her lemon.
31. The farmer milked his candle.
40. My mother knitted me a saw.
33. Tom hit a bump and fell off his tap.
34. Tony put a saddle on his pencil.
35. The kids fed the duck some stale scorpion.
36. The bartender poured the beer into a jug.
37. He placed the ring on her cat.
38. Some sports use a bat and a ball.
39. Lucy put the flowers in the trumpet.
40. To keep my trousers up I use a dolphin.
41. Most people live in a vest.
42. John swept the floor with a brush.
43. To get to work, I drive my helmet.
44. The kids fed the duck some stale bread.
45. Most wine is made from turtle.
46. Windy days are great for flying a couch.
47. The Time-keeper glanced at his jacket.
48. Tony put a saddle on his donkey.
49. The bartender poured the beer into a key.
50. My eyes water when I slice an onion.
51. While skiing, Jan broke her carrot.
52. The cowboy fired the chain.
53. To see in the cave we shone a lamb.
54. Tony put a saddle on his horse.
55. The farmer milked his doll.
56. While walking in the orchard, Tim picked one pear.
57. To keep the dogs out of the yard he put up a zip.
58. She wore a beautiful diamond ring.
59. Spot the dog slept outside in his note.
60. Julie fell down and skinned her branch.
61. He loosened the tie around his star.
62. While walking in the orchard, Tim picked one umbrella.
63. The boat passed easily under the goggles.
64. My eyes water when I slice an aeroplane.
65. At the circus you can see the silly scissors.
66. Lucy put the flowers in the toothbrush.
67. Some sports use a bat and a football.
68. My mother knitted me a bell.
69. The cowboy fired the gun.
70. The kids fed the duck some stale cake.

71. Most people live in a fly.
72. My mother knitted me a jumper.
73. Windy days are great for flying a kite.
74. John swept the floor with a broom.
75. Most people live in a barn.
76. My eyes water when I slice an eagle.
77. Most people eat with a knife and spoon.
78. Some sports use a bat and a skunk.
79. The children held hands and formed a square.
80. Windy days are great for flying a peg.
81. At the circus you can see the silly elephant.
82. She wore her socks and boots.
83. The boat passed easily under the arch.
84. John swept the floor with a piano.
85. The farmer milked his cow.
86. He placed the ring on her finger.
87. The hairdresser cut the man's hair.
88. He loosened the tie around his camel.
89. Carol sang and played her acoustic lips.
90. He hung his coat up on the butterfly.
91. The hairdresser cut the man's beard.
92. She wore her socks and rooster.
93. The boat passed easily under the squirrel.
94. To see in the cave we shone a lantern.
95. While skiing, Jan broke her arm.
96. The Time-keeper glanced at his cloud.
97. Most wine is made from snail.
98. Lucy put the flowers in the bowl.
99. Don't place all your eggs in the one cigarette.
100. He hung his coat up on the hanger.
101. While walking in the orchard, Tim picked one nail.
102. Windy days are great for flying a balloon.
103. The children held hands and formed a celery.
104. The bartender poured the beer into a lock.
105. The farmer milked his goat.
106. Most wine is made from cherries.
107. To see in the cave we shone a tyre.
108. The Time-keeper glanced at his clock.
109. Most people eat with a knife and comb.
110. The hairdresser cut the man's leaf.
111. She wore her socks and shoes.
112. Some sports use a bat and a desk.
113. She wore a beautiful diamond screwdriver.
114. While walking in the orchard, Tim picked one apple.
115. The bartender poured the beer into a ladder.
116. Tony put a saddle on his pen.
117. Most people eat with a knife and fork.
118. My mother knitted me a mitten.
119. Don't place all your eggs in the one camera.
120. Carol sang and played her acoustic guitar.
121. While skiing, Jan broke her coat.
122. The cowboy fired the anchor.
123. She wore her socks and window.
124. The children held hands and formed a yacht.
125. To keep my trousers up I use a cactus.
126. At the circus you can see the silly clown.
127. While skiing, Jan broke her leg.
128. Spot the dog slept outside in his cage.
129. Most people eat with a knife and mushroom.
130. Tony put a saddle on his claw.
131. She wore a beautiful diamond necklace.
132. At the circus you can see the silly needle.
133. He placed the ring on her dog.
134. The kids fed the duck some stale fire.
135. To keep the dogs out of the yard he put up a fence.
136. Julie fell down and skinned her knee.
137. To see in the cave we shone a torch.
138. John swept the floor with a drum.
139. Tom hit a bump and fell off his bike.
140. To get to work, I drive my cap.
141. The farmer milked his globe.
142. To keep my trousers up I use a rope.
143. Spot the dog slept outside in his coin.
144. Tom hit a bump and fell off his shower.
145. The boat passed easily under the acorn.
146. Carol sang and played her acoustic violin.
147. The children held hands and formed a dinghy.
148. John swept the floor with a frog.
149. Julie fell down and skinned her platypus.
150. Spot the dog slept outside in his spider.
151. He hung his coat up on the hook.
152. She wore a beautiful diamond mountain.
153. The cowboy fired the wheel.
154. To get to work, I drive my axe.
155. Most wine is made from chair.
156. He hung his coat up on the net.

157. Julie fell down and skinned her tree.
158. My eyes water when I slice an envelope.
159. While walking in the orchard, Tim picked one hammer.
160. To keep the dogs out of the yard he put up a button.
161. While skiing, Jan broke her hat.
162. To keep my trousers up I use a fish.
163. At the circus you can see the silly toe.
164. He loosened the tie around his comet.
165. Spot the dog slept outside in his kennel.
166. The kids fed the duck some stale chimney.
167. Don't place all your eggs in the one cigar.
168. Most people eat with a knife and pumpkin.
169. The boat passed easily under the bridge.
170. Tom hit a bump and fell off his snake.
171. Lucy put the flowers in the vase.
172. He loosened the tie around his neck.
173. Most people live in a bee.
174. Windy days are great for flying a stool.
175. The hairdresser cut the man's truck.
176. Peter read a chapter in his book.
177. The boys helped Jane wax her car.
178. My warm doona is filled with lots of yo-yo.
179. He mailed the letter without a stamp.
180. The queen wears a crown.

APPENDIX B 3

WORD ASSOCIATION TASK

Below you will see a series of word pairs, some are related in some way, some are not. Your task is to read each pair and decide how 'related' or 'associated' they are on a scale from
1 - 5 :

1		3		5
No Relation				Highly Related

For Example:

Carrot	Pea	5
Shoe	Beer	1

---

1. Pen Pencil
2. Window Chicken
3. Lock Key
4. Hammer Apple
5. Dolphin Belt
6. Lantern Torch
7. Candle Cow
8. Fire Chimney
9. Snake Shower
10. Boots Shoes
11. Tree Knee
12. Football Ball
13. Rope Belt
14. Dinghy Yacht
15. Fish Dolphin
16. Mitten Jumper
17. Piano Broom
18. Lemon Cat
19. Bee House
20. Moon Lips
21. Cage Kennel
22. Donkey Horse
23. Dog Cat
24. Cactus Dolphin
25. Needle Clown
26. Pear Apple
27. Cherries Grapes
28. Eagle Aeroplane
29. Comb Mushroom
30. Nose Lips
31. Balloon Kite
32. Yacht Circle
33. Clock Watch
34. Snail Turtle
35. Goat Cow
36. Axe Helmet
37. Coat Hat
38. Lips Guitar
39. Orange Onion
40. Scorpion Chimney
41. Wheel Anchor
42. Chair Turtle
43. Arm Leg
44. Peg Couch
45. Pumpkin Mushroom
46. Pencil Horse
47. Arch Bridge
48. Dress Watch
49. Waist Neck
50. Umbrella Hammer
51. Doll Candle
52. Mushroom Fork
53. Hat Leg
54. Zip Fence
55. Jacket Dress
56. Truck Bus
57. Cigarette Cigar
58. Chicken Shoes
59. Pig Torch
60. Claw Pencil
61. Church Jumper
62. Camera Cigar
63. Coin Kennel
64. Trumpet Accordion
65. Spoon Fork
66. Cat Finger
67. Skunk Desk
68. Celery Yacht
69. Star Neck
70. Stool Couch
71. Vest Bee
72. Bell Church
73. Acorn Bridge
74. Jug Glass
75. Branch Tree
76. Toothbrush Accordion
77. Square Circle
78. Butterfly Hook
79. Thumb Finger
80. Screwdriver Screw
81. Lamb Pig
82. Net Butterfly
83. Note Coin
84. Elephant Clown
85. Globe Candle
86. Necklace Ring
87. Hanger Hook
88. Helmet Car
89. Frog Piano
90. Bowl Vase

91. Cloud Dress
92. Bus Hair
93. Nail Hammer
94. Scissors Needle
95. Mountain Screw
96. Telephone Desk
97. Envelope Aeroplane
98. Couch Kite
99. Ladder Key
100. Fly Bee
101. Barrel Basket
102. Turtle Grapes
103. Chain Anchor
104. Brush Broom
105. Shower Bike
106. Rooster Chicken
107. Wall Fence
108. Accordion Vase
109. Button Zip
110. Squirrel Acorn
111. Violin Guitar
112. Sled Bike
113. Platypus Tree
114. Saw Church
115. Barn House
116. Tyre Pig
117. Elbow Knee
118. Beard Hair
119. Spider Coin
120. Cake Bread
121. Rocket Butterfly
122. Drum Piano
123. Comet Star
124. Desk Ball
125. Carrot Hat
126. Cannon Gun
127. Cap Helmet
128. Toe Needle
129. Chimney Bread
130. Anchor Gun
131. Picture Zip
132. Key Glass
133. Tap Shower
134. Motorcycle Car
135. Aeroplane Onion
136. Screw Ring
137. Leaf Bus
138. Goggles Acorn
139. Cigar Basket
140. Camel Star

APPENDIX C

SUBJECT INSTRUCTIONS

1. GROUP WW

• Acquisition Phase - word (w)

This is an experiment on language comprehension and it's associated brain activity. On the screen in front of you a series of unconnected sentences of varying length will be presented one word at a time. Each sentence will be concluded by 2 words, again presented one at a time. The words concluding each sentence will sometimes complete the sentence sensibly, and sometimes not. Your task is to read each word silently as it is presented and pay particular attention to the final word and decide whether or not this particular word completed the sentence correctly.

On concluding this part of the experiment you will be given a rest, and when you're ready a memory test will begin, so make sure you pay attention to the sentences and the final words. I'll tell you more about that then though.

Make sure you keep your eyes as still as you can (fixated on the spot in the centre of the screen) and if you need to blink or move them, try and wait until the new sentence begins.

Five practice sentences will start the experiment so you know what to expect, then we will begin recording. Any Questions?

• Memory Phase - word (w)

You will now be presented with a list of words (one at a time), some of these words you will recognise as being the same as the final word from the sentences you saw before, some will be totally new to you (ie it did not conclude any sentences). Your task is to press the button on your right if you think the word concluded one of the sentences, or press the button on your left if it is a new word - press the button as quickly as you can after you have read the word.

So, if you recognise the word, press the button on the right, and if you dont, press the button on the left.

Again, try not to blink or move your eyes while the word is being presented and try to keep them fixated on the spot in the centre of the screen. If you need to blink, the best time is immediately after you've heard the beep which will signal the next word. Any Questions?

2. GROUP WP

• Acquisition Phase - word (w)

This is an experiment on language comprehension and it's associated brain activity. On the screen in front of you a series of unconnected sentences of varying length will be presented one word at a time. Each sentence will be concluded by 2 words, again presented one at a time. The words concluding each sentence will sometimes complete the sentence sensibly, and sometimes not. Your task is to read each word silently as it is presented and pay particular attention to the final word and decide whether or not this particular word completed the sentence correctly.

On concluding this part of the experiment you will be given a rest, and when you're ready a memory test will begin, so make sure you pay attention to the sentences and the final words. I'll tell you more about that then though.

Make sure you keep your eyes as still as you can (fixated on the spot in the centre of the screen) and if you need to blink or move them, try and wait until the new sentence begins.

Five practice sentences will start the experiment so you know what to expect, then we will begin recording. Any Questions?

- **Memory Phase - picture (p)**

You will now be presented with a series of pictures (one at a time), some of these pictures you will recognise as being representative of a word which concluded a sentence in the first part of the experiment, some will be totally new to you (ie it did not conclude any sentences). Your task is to press the button on your right if you think the picture (representing a word you saw before) concluded one of the sentences, or press the button on your left if it is a new picture (ie. the word it represents did not conclude a sentence)- press the button as quickly as you can after you have identified the picture.

So, if you recognise the picture, press the button on the right, and if you don't, press the button on the left.

Again, try not to blink or move your eyes while the picture is being presented and try to keep them fixated on the spot in the centre of the screen. If you need to blink, the best time is immediately after you've heard the beep which will signal the next picture. Any Questions?

3. GROUP PP

- **Acquisition Phase - picture (p)**

This is an experiment on language comprehension and it's associated brain activity. On the screen in front of you a series of unconnected sentences of varying length will be presented one word at a time. Each sentence will be concluded by 2 pictures, again presented one at a time. The pictures concluding each sentence will sometimes complete the sentence sensibly, and sometimes not. Your task is to read each word silently as it is presented and pay particular attention to the final picture and decide whether or not this particular picture completed the sentence correctly (ie it makes sense).

On concluding this part of the experiment you will be given a rest, and when you're ready a memory test will begin, so make sure you pay attention to the sentences and the final pictures. I'll tell you more about that then though.

Make sure you keep your eyes as still as you can (fixated on the spot in the centre of the screen) and if you need to blink or move them, try and wait until the new sentence begins.

Five practice sentences will start the experiment so you know what to expect, then we will begin recording. Any Questions?

- **Memory Phase - picture (p)**

You will now be presented with a series of pictures (one at a time), some of these pictures you will recognise as being the same as the final picture from the sentences you saw before, some will be totally new to you (ie it did not conclude any sentences). Your task is to press the button on your right if you think the picture concluded one of the sentences, or press the button on your left if it is a new picture - press the button as quickly as you can after you have identified the picture.

So, if you recognise the picture, press the button on the right, and if you dont, press the button on the left.

Again, try not to blink or move your eyes while the picture is being presented and try to keep them fixated on the spot in the centre of the screen. If you need to blink, the best time is immediately after you've heard the beep which will signal the next picture. Any Questions?

4. GROUP PW

- **Acquisition Phase - picture (p)**

This is an experiment on language comprehension and it's associated brain activity. On the screen in front of you a series of unconnected sentences of varying length will be presented one word at a time. Each sentence will be concluded by <u>2 pictures</u>, again presented one at a time. The pictures concluding each sentence will sometimes complete the sentence sensibly, and sometimes not. Your task is to read each word silently as it is presented and pay particular attention to the <u>final</u> picture and decide whether or not this particular picture completed the sentence correctly.

On concluding this part of the experiment you will be given a rest, and when you're ready a memory test will begin, so make sure you pay attention to the sentences and the final pictures. I'll tell you more about that then though.

Make sure you keep your eyes as still as you can (fixated on the spot in the centre of the screen) and if you need to blink or move them, try and wait until the new sentence begins.

Five practice sentences will start the experiment so you know what to expect, then we will begin recording. Any Questions?

- **Memory Phase - word (pw)**

You will now be presented with a list of words (one at a time), some of these words you will recognise as being the <u>name of a picture</u> which concluded a sentence in the first part of the experiment, some will be totally new to you (ie its picture did not conclude any sentences). Your task is to press the button on your right if you think the word (representing the picture) concluded one of the sentences, or press the button on your left if it is a new word - press the button as quickly as you can after you have read the word.

So, if you recognise the word, press the button on the right, and if you dont, press the button on the left.

Again, try not to blink or move your eyes while the word is being presented and try to keep them fixated on the spot in the centre of the screen. If you need to blink, the best time is immediately after you've heard the beep which will signal the next word. Any Questions?

APPENDIX D:

MEANS TABLES FROM ACQUISTION AND MEMORY PHASES

Table D1: Means Table from 5-way ANOVA conducted on N400 Amplitude data for the Acquisition Phase.

SITE	Prime Words: IC	Prime Words: RC	Prime Words: UC	Target Words: IC	Target Words: RC	Target Words: UC
Fz	-1.56	-3.53	-5.58	0.09	-1.91	-1.6
Cz	-0.89	-3.75	-5.99	1.07	4.54	0
Pz	0.98	-1.24	-2.95	2.61	3.67	2.28
P3	2.79	0.16	-0.8	3.44	4.8	3.25
P4	1.64	-0.71	-1.5	1.9	4.02	4.51

Prime Pictures: IC	Prime Pictures: RC	Prime Pictures: UC	Target Pictures: IC	Target Pictures: RC	Target Pictures: UC
-4.72	-7.4	-7.29	1.39	-2.35	-0.69
-0.41	-4.1	-5.09	1.84	2.9	2.15
5.33	2.53	0.34	2.6	8.13	6.04
7.15	4.97	3.36	3.39	8.52	8.6
6.37	5.9	4.59	3.19	9.16	10.17

Prime Words: II	Prime Words: RI	Prime Words: UI	Target Words: II	Target Words: RI	Target Words: UI
-4.08	-5.3	-4.98	0.75	-1.26	-3.37
-4.01	-6.25	-5.04	4.23	-2.32	-0.88
-1.13	-3.62	-1.9	3.78	1.56	0
0.49	-1.42	-0.62	4.08	3.06	1.29
-0.44	-2.3	-1.46	2.8	2.54	0.72

Prime Pictures: II	Prime Pictures: RI	Prime Pictures: UI	Target Pictures: RI	Target Pictures: UI	Target Pictures: II
-7.22	-8.5	-8.9	-4.84	-4.9	0.38
-3.62	-6.1	-5.7	-4.17	-3.75	-0.69
2.03	0.26	0.05	0.17	2.27	2.8
5.18	3.52	3.66	2.95	4.49	3.68
6.2	4.1	3.0[illegible]	5.51	6.51	5.9

Table D2: Means Table from 5-way ANOVA conducted on N400 Latency data for the Acquisition Phase.

SITE	Prime Words: IC	Prime Words: RC	Prime Words: UC	Target Words: IC	Target Words: RC	Target Words: UC
Fz	359	384	383	387	373	376
Cz	341	382	375	369	348	357
Pz	358	384	377	378	383	381
P3	406	411	410	417	405	421
P4	422	419	425	408	389	408

SITE	Prime Pictures: RC	Prime Pictures: UC	Prime Pictures: IC	Target Pictures: IC	Target Pictures: RC	Target Pictures: UC
Fz	395	356	348	361	355	383
Cz	379	372	363	364	351	370
Pz	386	383	374	381	407	375
P3	433	405	411	364	429	369
P4	415	437	438	383	436	391

SITE	Prime Words: II	Prime Words: RI	Prime Words: UI	Target Words: II	Target Words: RI	Target Words: UI
Fz	390	388	363	320	377	369
Cz	378	382	380	368	367	364
Pz	379	386	398	361	381	393
P3	407	412	411	365	399	407
P4	416	424	435	343	400	406

SITE	Prime Pictures: II	Prime Pictures: RI	Prime Pictures: UI	Target Pictures: II	Target Pictures: RI	Target Pictures: UI
Fz	353	379	378	359	349	355
Cz	352	362	365	338	355	384
Pz	362	373	388	320	366	378
P3	403	386	410	347	384	417
P4	423	413	415	394	373	413

Table D3: Means Table from 5-way ANOVA conducted on LPC Amplitude data for the Acquisition Phase.

SITE	Prime Words : IC	Prime Words : RC	Prime Words : UC	Target Words : IC	Target Words : RC	Target Words : UC
Fz	2.8	4.1	2.1	4.3	5	5.9
Cz	4.3	4.9	3.7	5.6	7.3	7.6
Pz	5.1	5	5.5	5.1	7.4	7.7
P3	3.8	4.5	4.9	4.3	6.4	6.8
P4	4.1	4.2	4.3	4.1	6.2	7.3

SITE	Prime Pictures: IC	Prime Pictures: RC	Prime Pictures: UC	Target Pictures: IC	Target Pictures: RC	Target Pictures: UC
Fz	5	4.5	1.9	4.4	7.4	8.2
Cz	10.3	7.7	5.6	5	10.4	11.4
Pz	10.8	7.5	4.8	4.1	10.7	10.1
P3	8.7	5.9	3.1	3.1	10.1	9.6
P4	8.2	6.1	3.9	3.6	9	8

SITE	Prime Words : II	Prime Words : RI	Prime Words : UI	Target Words : II	Target Words : RI	Target Words : UI
Fz	3.8	2.8	3.3	8.5	6.5	5.4
Cz	5.7	3.9	5.4	10.5	8.6	6.7
Pz	7.1	5.6	7.4	10.6	9.5	7.4
P3	7.2	5.2	6.8	8.8	9.3	7.6
P4	6.2	4.2	5.6	9.3	9	7.1

SITE	Prime Pictures: II	Prime Pictures: RI	Prime Pictures: UI	Target Pictures: II	Target Pictures: RI	Target Pictures: UI
Fz	2.3	1.3	1.2	5.3	5.9	7.4
Cz	7.3	5.1	6.5	8	8.7	9.2
Pz	5.7	5.8	6.6	7	9.2	9.4
P3	5.2	4.5	5.1	6.4	8.7	8.5
P4	5.6	4.7	5.5	7.7	9.6	8.2

Table D4: Means Table from 5-way ANOVA conducted on LPC Latency data for the Acquisition Phase.

SITE	Prime Words: IC	Prime Words: RC	Prime Words: UC	Target Words: IC	Target Words: RC	Target Words: UC
Fz	684	696	676	682	682	683
Cz	673	656	675	687	660	686
Pz	676	690	670	682	653	679
P3	676	686	663	680	676	703
P4	665	693	679	710	667	688

SITE	Prime Pictures: IC	Prime Pictures: RC	Prime Pictures: UC	Target Pictures: IC	Target Pictures: RC	Target Pictures: UC
Fz	650	732	696	691	671	671
Cz	649	705	647	719	672	637
Pz	643	655	689	673	634	698
P3	640	674	690	695	644	666
P4	641	647	667	687	658	720

SITE	Prime Words: II	Prime Words: RI	Prime Words: UI	Target Words: II	Target Words: RI	Target Words: UI
Fz	650	653	684	699	686	691
Cz	658	646	673	684	668	674
Pz	664	665	650	691	655	651
P3	639	666	656	702	667	651
P4	652	660	646	678	669	665

SITE	Prime Pictures: II	Prime Pictures: RI	Prime Pictures: UI	Target Pictures: II	Target Pictures: RI	Target Pictures: UI
Fz	685	645	679	683	660	678
Cz	668	645	665	643	654	651
Pz	716	644	656	687	644	638
P3	703	655	679	667	644	646
P4	661	663	637	671	643	644

Table D5: Means Table from 3-way ANOVA conducted on N400 Amplitude data for the Memory Phase.

SITE	WW Seen	WW Unseen	WP Seen	WP Unseen	PW Seen	PW Unseen	PP Seen	PP Unseen
Fz	-5	-11	-10.6	-8.6	-7.4	-9.7	-8.6	-11.4
Cz	-6.9	-7.6	-10.3	-9.4	-9.2	-10.6	-6.2	-10.2
Pz	-5.1	-5.2	1	-1.1	-3.6	-5.9	0.9	-1.9
P3	-2.8	-5.5	-2.6	1	-2.6	-6.3	5.2	-0.9
P4	-3.8	-4.8	-4.3	-0.6	-4	-6.6	2.4	-1.4

Table D6: Means Table from 3-way ANOVA conducted on N400 Latency data for the Memory Phase.

WW Seen	WW Unseen	WP Seen	WP Unseen	PW Seen	PW Unseen	PP Seen	PP Unseen
376	383	364	336	392	412	348	349
373	398	374	355	393	409	350	354
378	390	400	353	378	433	311	386
418	414	440	372	376	424	373	432
423	423	457	424	426	444	395	432

Table D7: Means Table from 3-way ANOVA conducted on LPC Amplitude data for the Memory Phase.

SITE	WW Seen	WW Unseen	WP Seen	WP Unseen	PW Seen	PW Unseen	PP Seen	PP Unseen
Fz	6.7	1.7	1.9	2.6	4.6	2.2	4.6	6.1
Cz	7.3	5.8	6	3.3	10.5	2.9	15.6	9.8
Pz	8	5.9	7.7	5.9	12.8	3	16.2	8.8
P3	7.9	3.8	3.9	1.5	13.3	2.8	13.6	6.4
P4	5.6	3.1	3	1.9	9.6	0.4	12.6	6.8

Table D8: Means Table from 3-way ANOVA conducted on LPC Latency data for the Memory Phase.

WW Seen	WW Unseen	WP Seen	WP Unseen	PW Seen	PW Unseen	PP Seen	PP Unseen
696	698	729	731	694	712	642	686
671	686	759	704	681	706	592	653
658	651	691	678	666	669	589	691
657	681	692	680	662	682	621	674
636	651	691	669	661	702	633	696

Table D9: Means Table from 3-way ANOVA conducted on RT data for the Memory Phase.

	Memory Stimulus (RT)	Word-Word	Word-Picture	Picture-Word	Picture-Picture
1	Seen	879.1	1049.4	836.9	773.4
2	Unseen	884.4	1041.4	812.9	549.9

	Correct Rej.	Acq. Stim	Mstim (words)	Mstim (pics)
1		Words	25.5	24.4
2		Pictures	25.3	28.6
3				
4	False Alarms			
5		Words	3.6	5.6
6		Pictures	5.6	3.7
7				
8	Hits			
9		Words	46.1	47.3
10		Pictures	41.4	55.4
11				
12	Misses			
13		Words	13.5	11.9
14		Pictures	18.7	11.1

APPENDIX E :

ANOVA TABLES FROM ACQUISITION AND MEMORY PHASES

Table E1: Anova Table for N400 Amplitude data from Acquisition Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Stimulus Position	1	6779.4	6779.4	50.4	.000	***
Sentence	1	1996.4	1996.4	33.89	.000	***
Prime Type	2	1180	590	12.2	.000	***
Site	4	20503	5125	62.9	.000	***
Stimulus Mode x Site	4	3959	989	12.1	.000	***
Stimulus Position x Site	4	642.5	160.6	12.1	.000	***
Sentence x Site	4	125	31.3	5.6	.000	***
Prime Type x Site	8	583.6	72.9	15.3	.000	***
Stimulus Position x Sentence x Site	2	1087.5	543.7	7.1	.001	**
Stimulus Mode x Stimulus Position x Site	4	537	134.4	10.1	.000	***
Stimulus Mode x Sentence x Site	4	80.1	20	3.7	.01	*
Stimulus Position x Sentence x Site	4	54.8	13.7	2.8	.026	*
Stimulus Mode x Prime Type x Site	8	136.2	17.02	3.6	.001	**

Table E2: Anova Table for N400 Latency data from Acquisition Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Stimulus Position	1	104834	104834	6.46	.015	*
Prime Type	2	104849	52424	7.12	.001	**
Site	4	795457	198864	27.1	.000	***

Table E3: Anova Table for LPC Amplitude data from Acquisition Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Stimulus Position	1	3427	3427	18.7	.000	***
Site	4	2322	580.7	13.8	.000	***
Stimulus Mode x Prime Type	1	801.3	801.3	7.4	.001	**
Stimulus Position x Sentence	1	313	313	5.7	.02	*
Stimulus Position x Prime Type	2	1259.5	629.7	6.4	.002	**
Sentence x Site	4	153.8	38.5	8.8	.000	***
Stimulus Mode x Stimulus Position x Prime	2	999.8	499.9	5.1	.01	*
Stimulus Position x Prime Type x Site	8	160.7	20.1	3.6	.000	***

Table E4: Anova Table for LPC Latency data from Acquisition Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Sentence	1	82664	82664	5.9	.02	*
Stimulus Position x Prime	2	94103	470521	5.4	.01	*
Sentence x Prime Type x Site	8	120655	15081	4.1	.000	***

Table E5: Anova Table for N400 Amplitude data from Memory Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Stimulus Type	1	288.1	288.1	6.7	.01	*
Site	4	4030	1007.7	28.8	.000	***
Acquisition Stimuli x Stimulus Type	1	208.2	208.2	4.85	.03	*
Memory Stimuli x Site	4	735	183.8	5.3	.001	**

Table E6: Anova Table for N400 Latency data from Memory Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Site	4	190325	47581	18.01	.000	***
Acquisition Stimuli x Stimulus Type	1	58021	58021	12.26	.001	**
Acquisition Stimuli x Stimulus Type x Site	4	25692	6422	3.4	.01	*

Table E7: Anova Table for LPC Amplitude data from Memory Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Acquisition Stimuli	1	1286	1286	4.8	.03	*
Stimulus Type	1	1977	1977	18.7	.000	***
Site	4	975	243.7	7.2	.000	***
Acquisition Stimuli x Stimulus Type	1	493	493	4.6	.03	*
Memory Stimuli x Site	4	174	43.6	8.7	.000	***
Acquisition Stimuli x Stimulus Type x Site	4	145.1	36.3	7.2	.000	***

Table E8: Anova Table for LPC Latency data from Memory Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Site	4	86247	17061	3.2	.01	*
Acquisition Stimuli x Memory Stimulus	1	119284	119284	9.14	.004	**
Acquisition Stimuli x Stimulus Type	1	56942	56942	4.9	.03	*

TableE 9: Anova Table for RT data from Memory Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
Acquisition Stimuli	1	956920	956920	13.3	.001	**
Acquisition Stimuli x Memory Stimulus	1	527167	527167	7.3	.01	*

Table E10: Anova Table for False Alarm and Hit data from Memory Phase

Source	df	S of S	Mean Sq.	F Value	p Value	Sig
(False Alarm) Aquisition Stimulus x Memory Stimulus	1	34.8	34.8	3.2	.078	ns
(Hits) Acquisition Stimuli	1	572.2	572.2	3.4	.074	ns

APPENDIX F:

N400 AND LPC AMPLITUDE AND LATENCY FIGURES

FOR BOTH THE ACQUISITION AND MEMORY PHASES

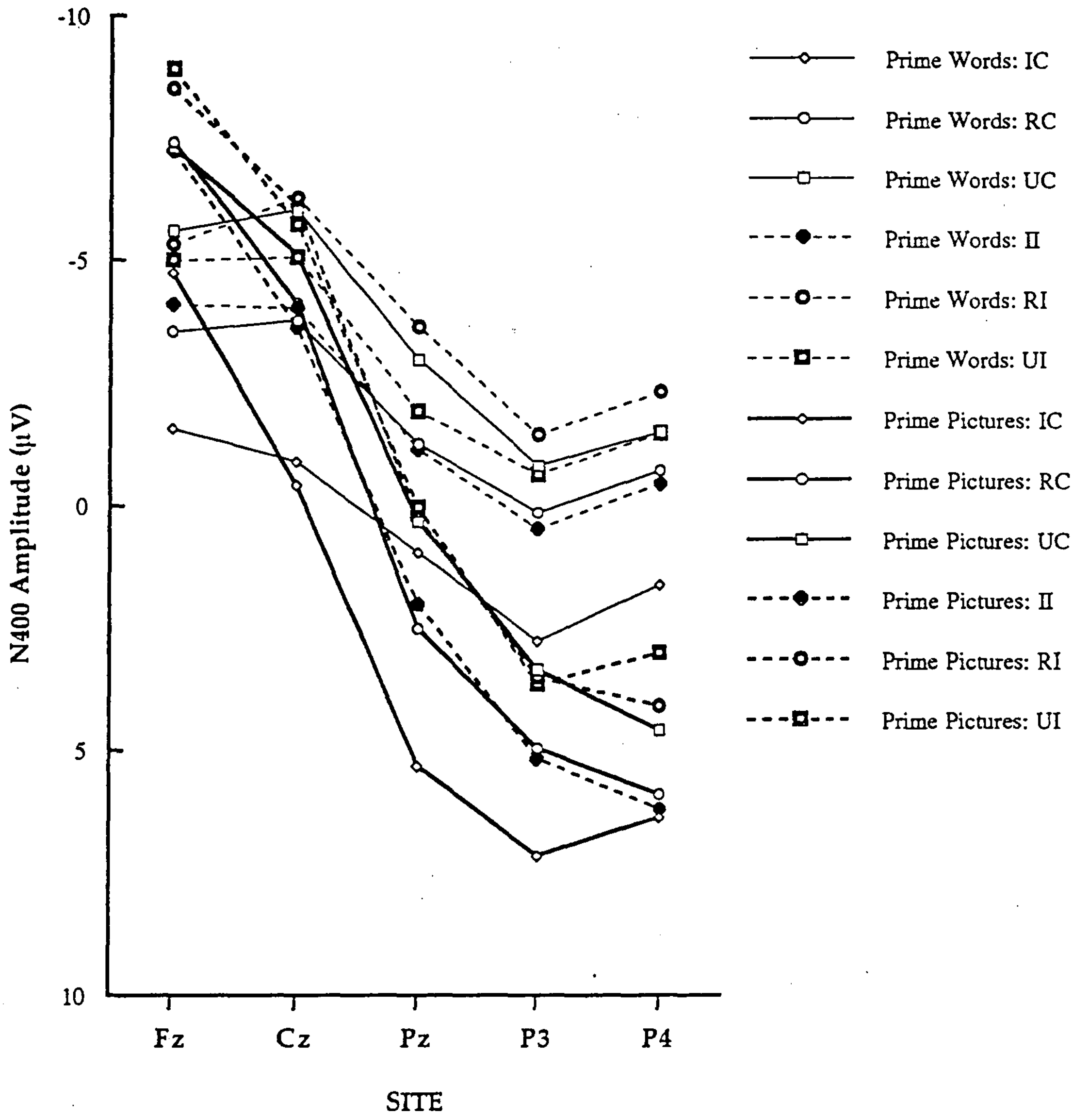

Figure F1: N400 Amplitude mean data for Prime Position Pictures and Words for each Prime Type at each site.

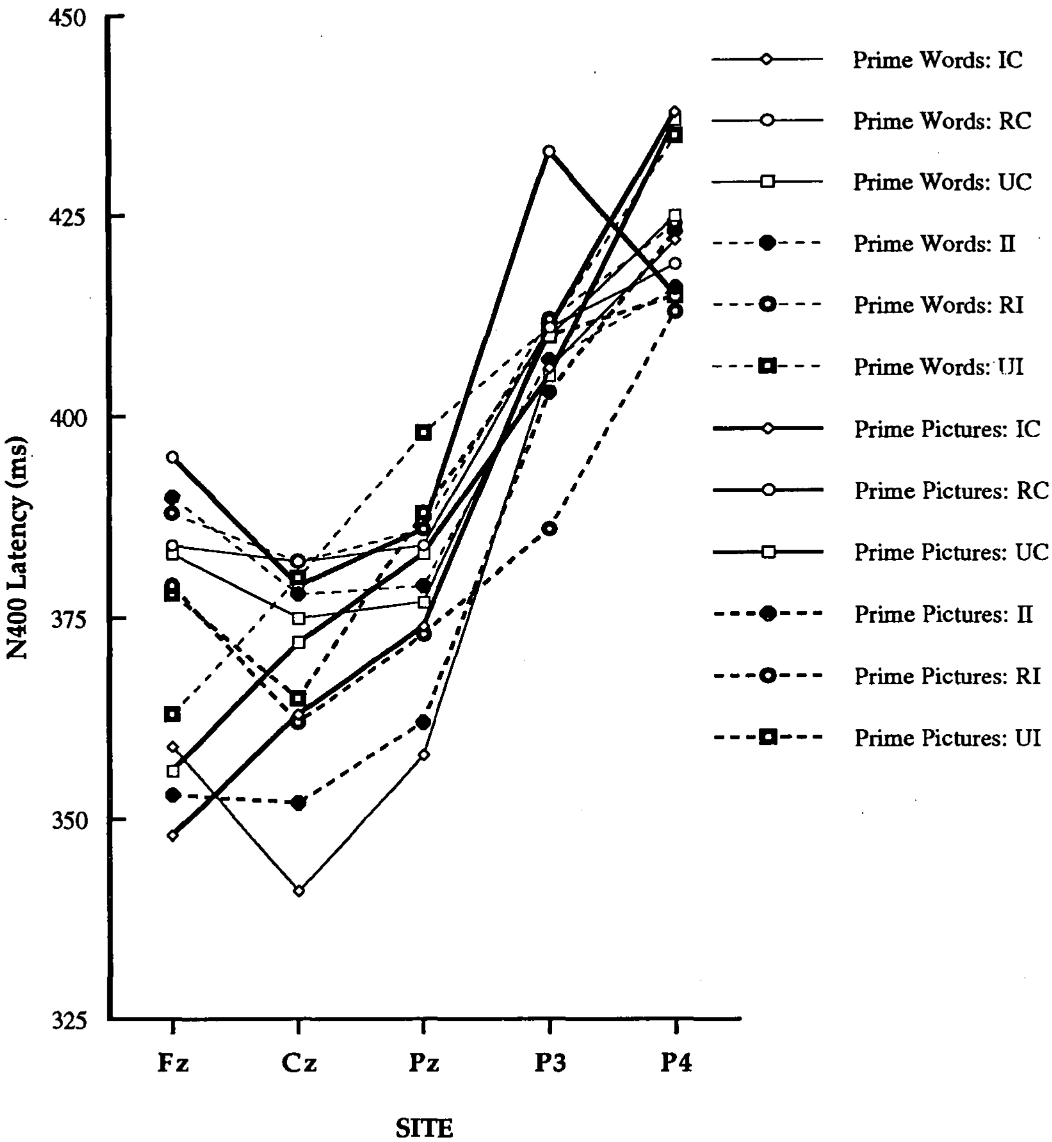

Figure F2 : N400 Latency mean data for Prime Position Pictures and Words for each Prime Type at each site.

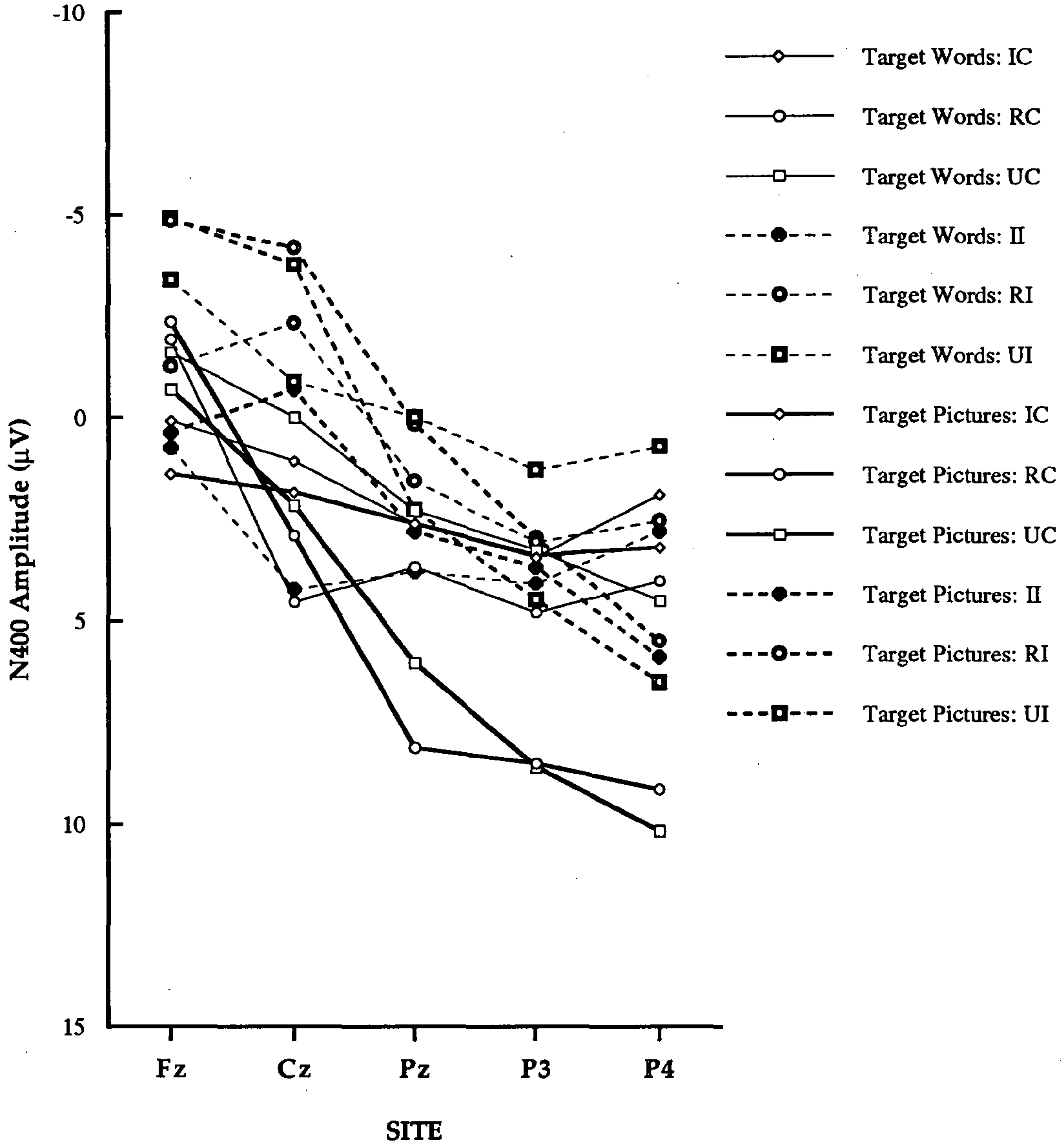

Figure F3: N400 Amplitude mean data for Target Position Pictures and Words for each Prime type at each site.

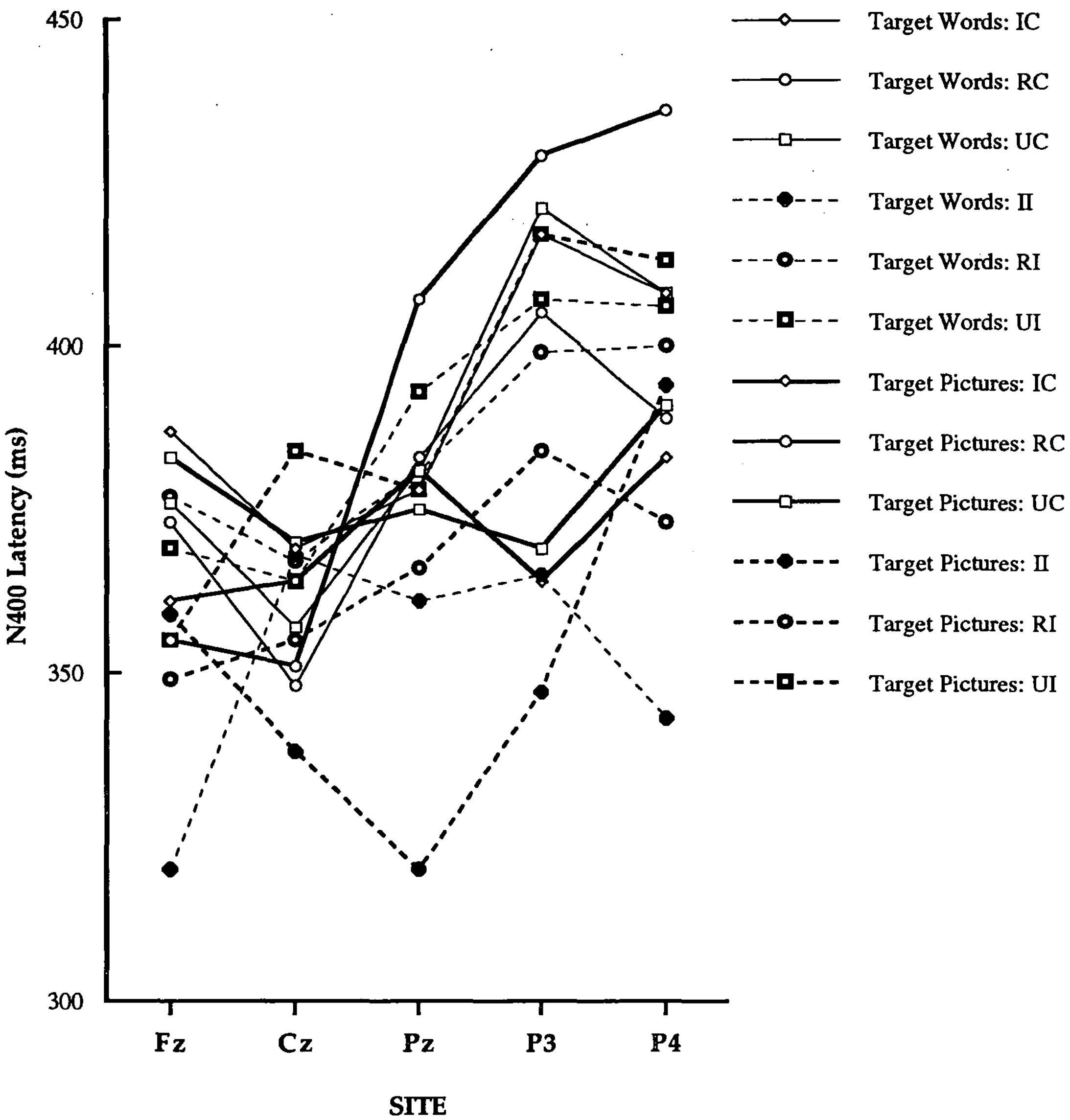

Figure F4: N400 Latency mean data for Target Position Picture and Words for each Prime Type at each site.

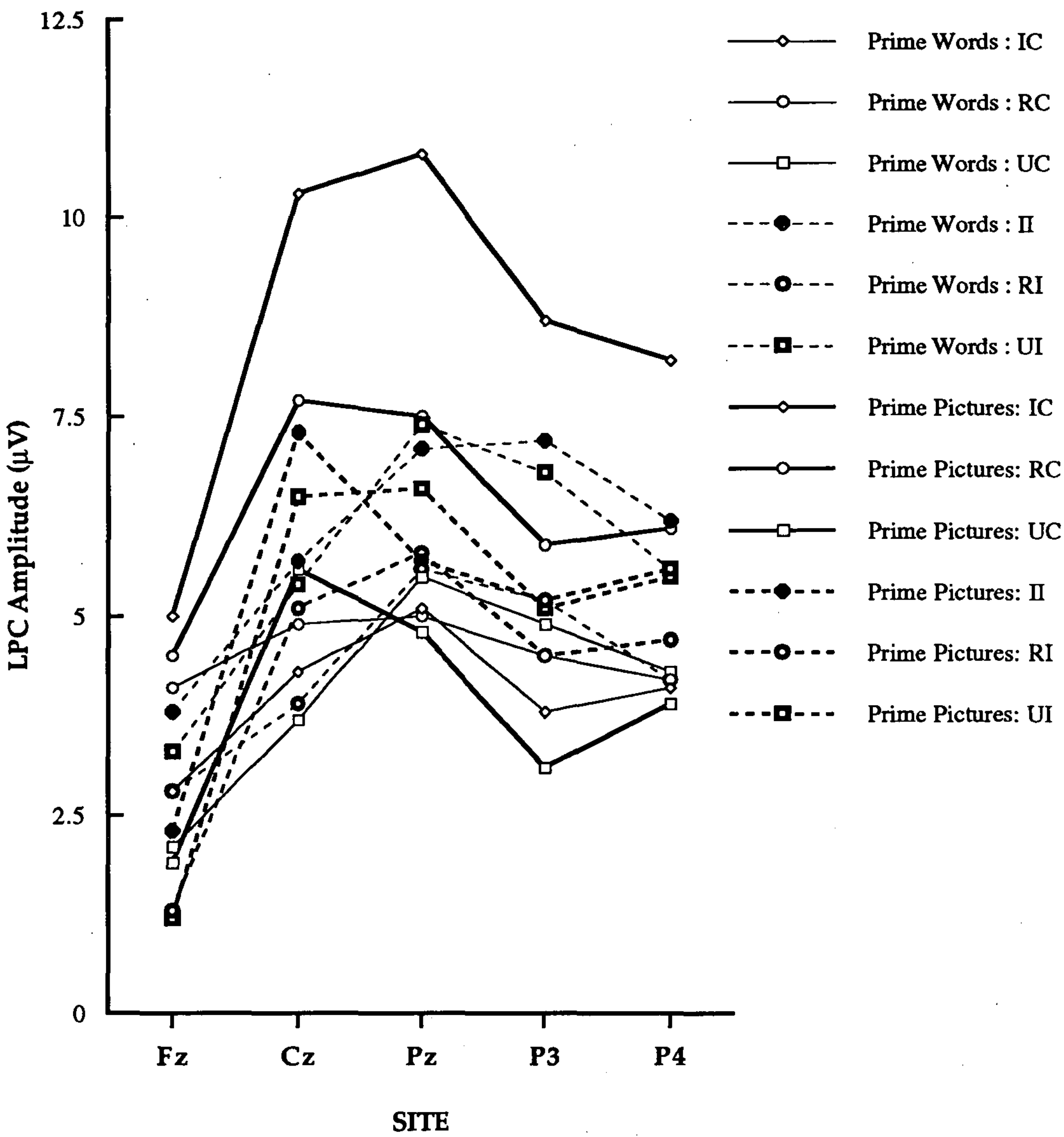

Figure F5: LPC Amplitude mean data for Prime Position Pictures and Words for each Prime Type at each site.

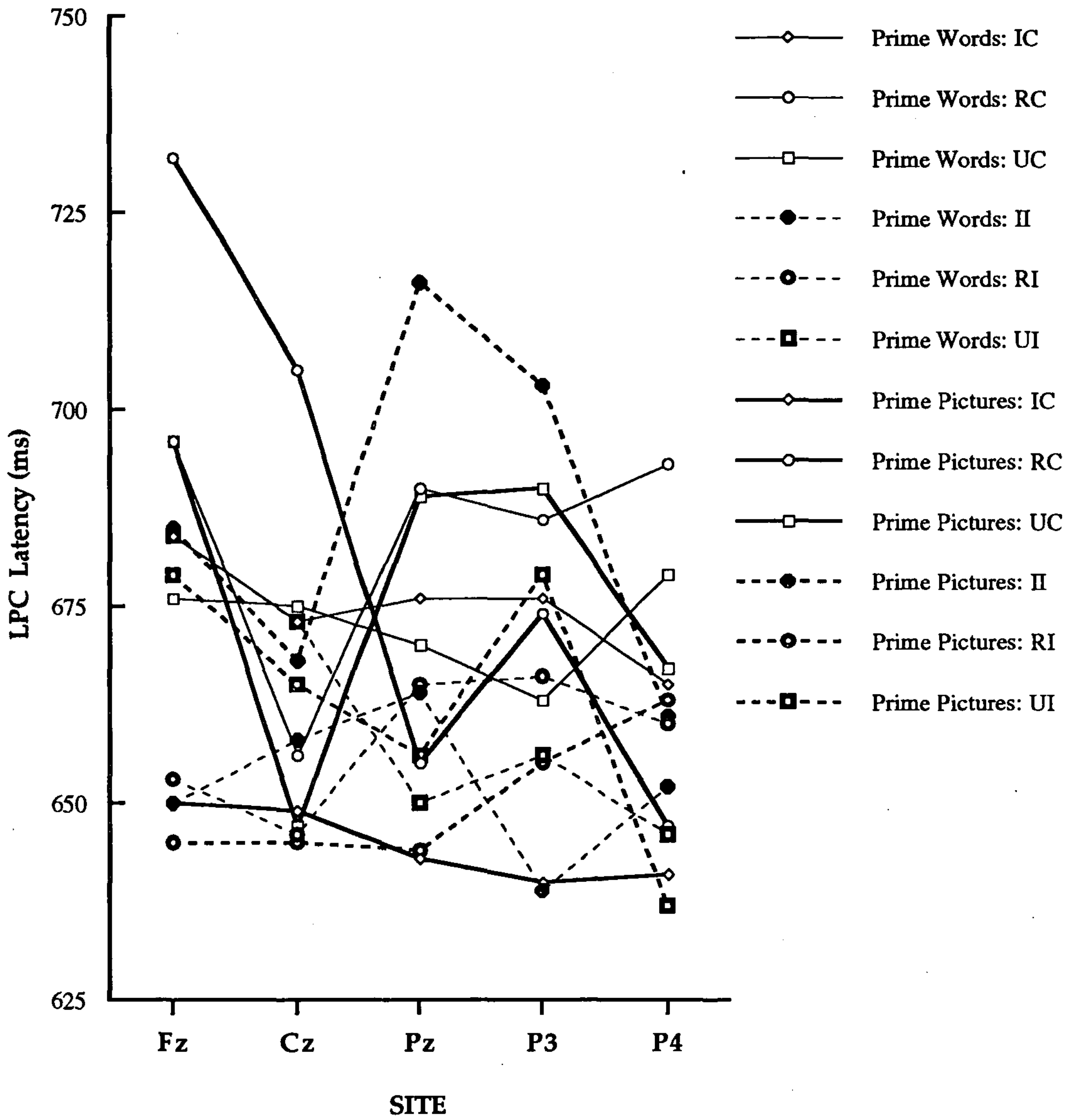

Figure F6: LPC Latency mean data for Prime Position Pictures and Words for each Prime Type at each site.

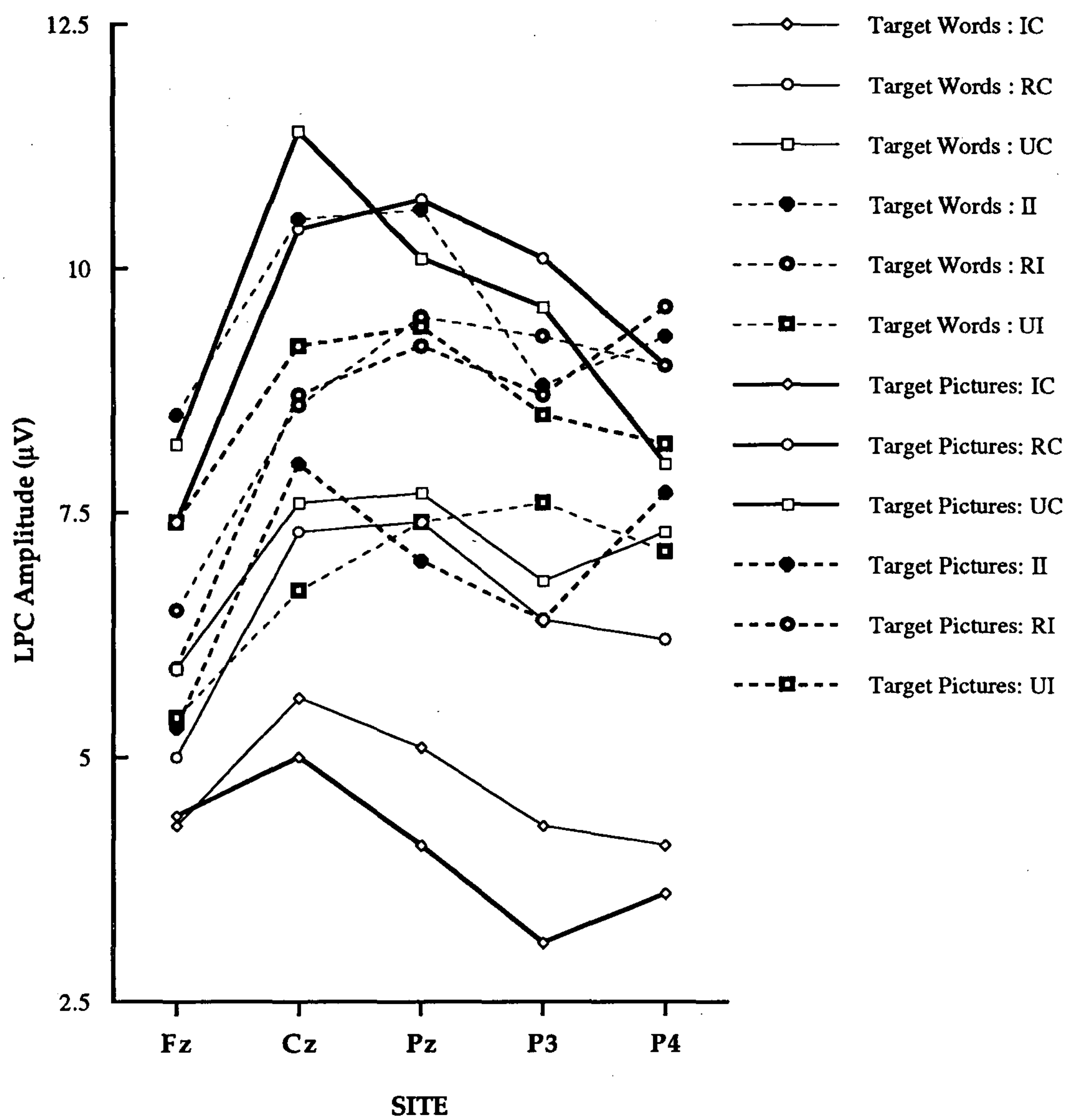

Figure F7: LPC Amplitude mean data for Target Position Pictures and Words for each Prime Type at each site.

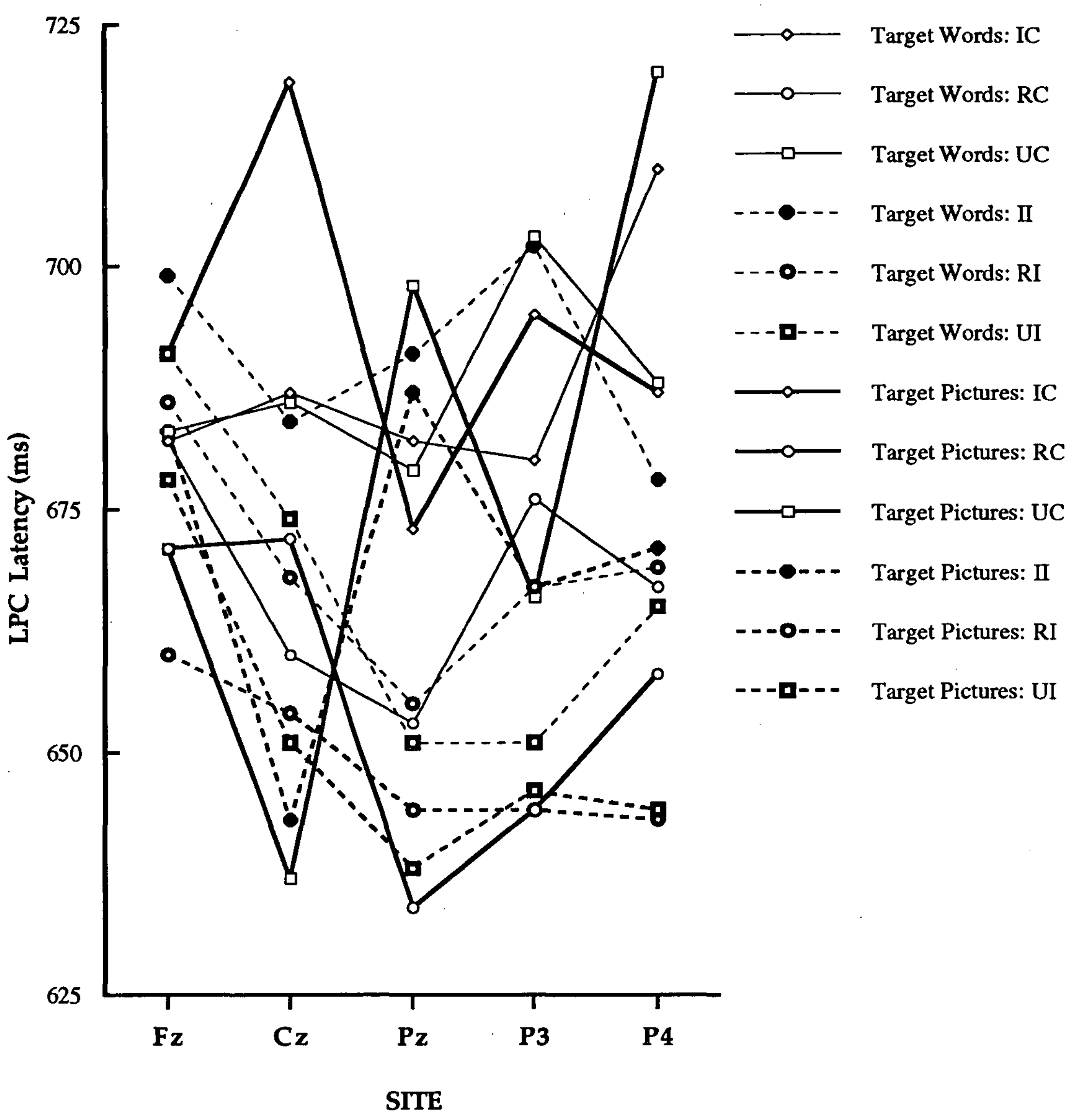

Figure F8: LPC latency mean data for Target Position Pictures and Words for each Prime type at each site.

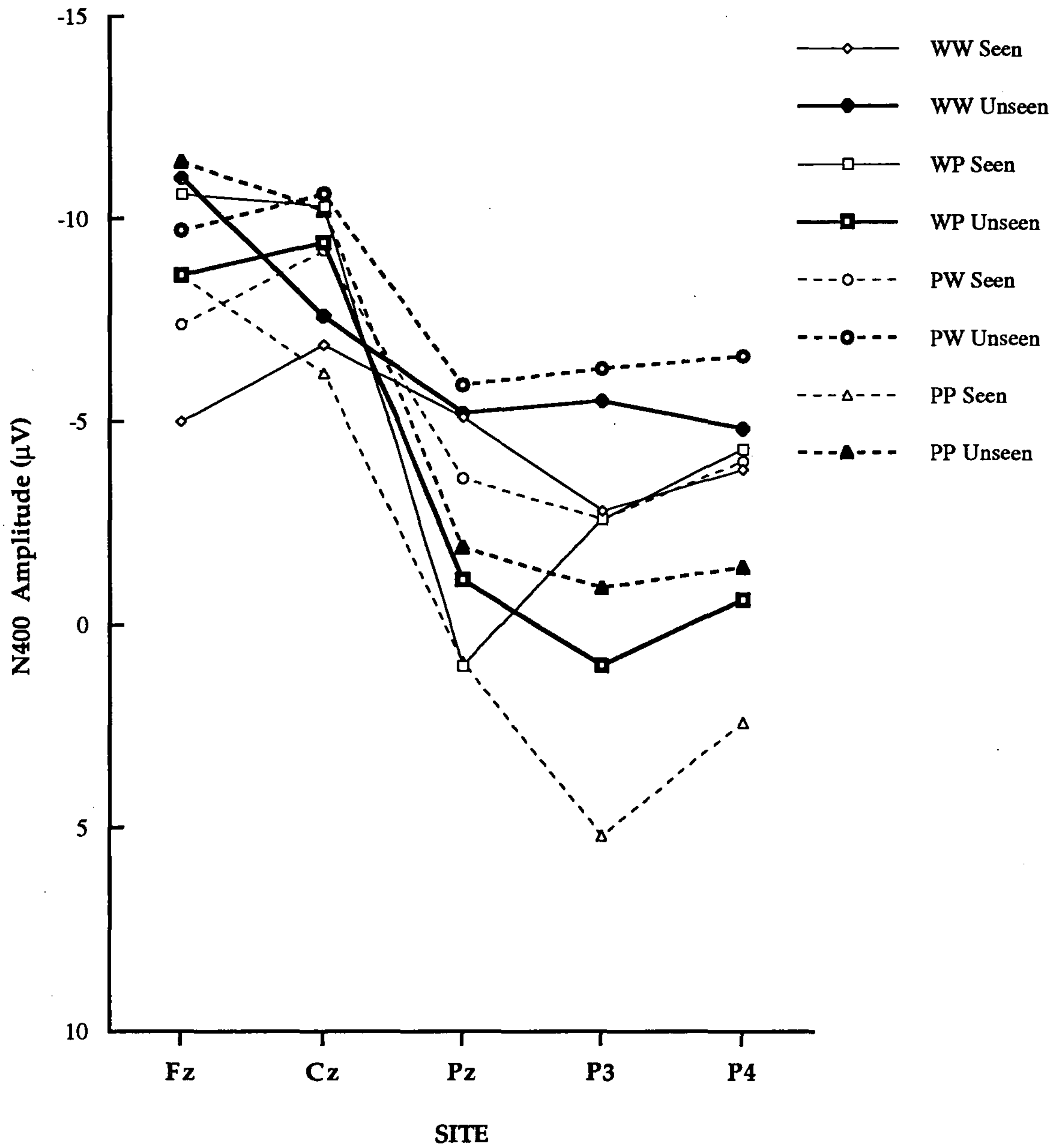

Figure F9: N400 Amplitude mean data for Seen and Unseen Stimuli for each subject group in the Memory Phase across each site.

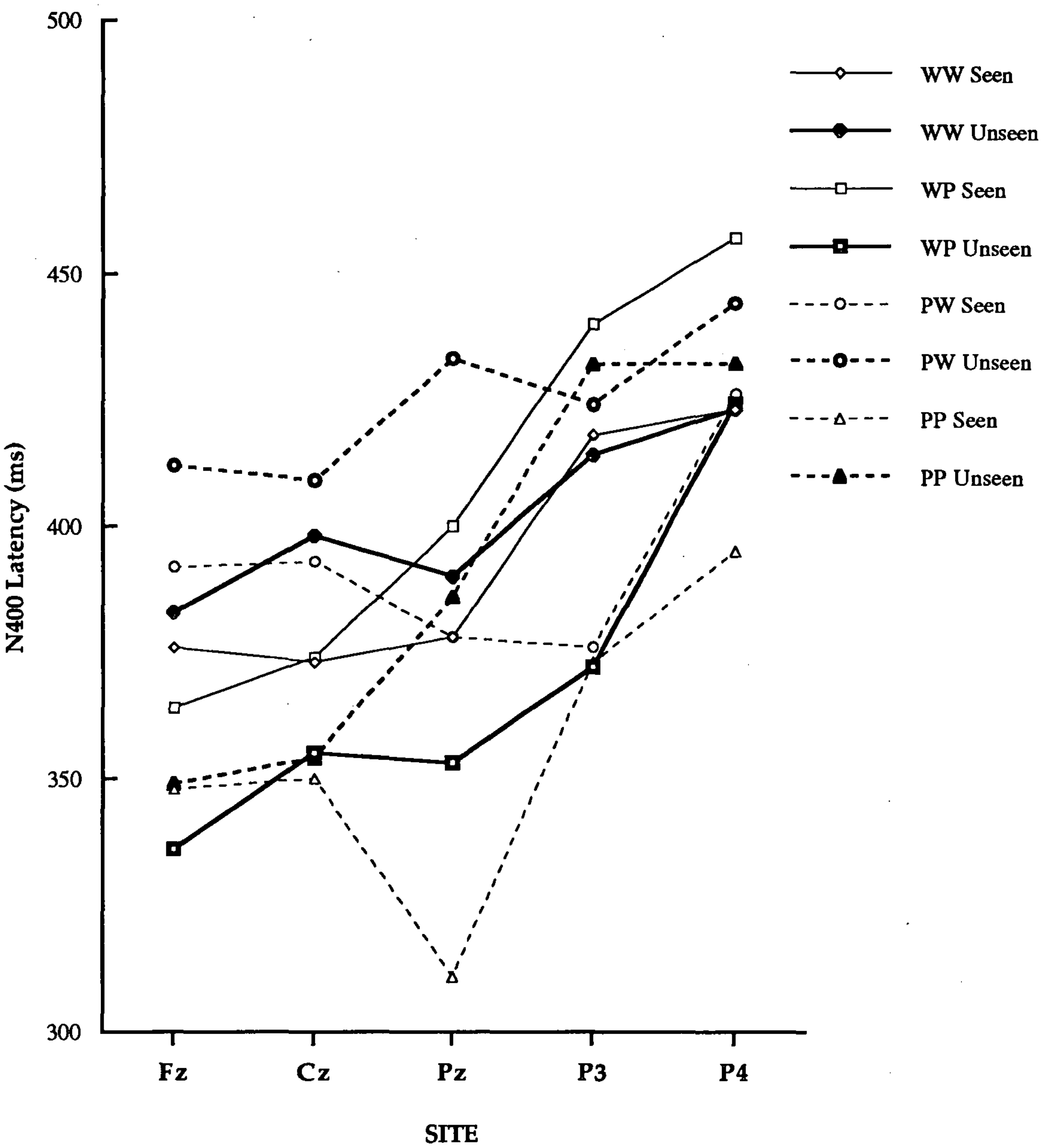

Figure F10: N400 Latency mean data for Seen and Unseen Stimuli for each subject group in the Memory Phase across each site.

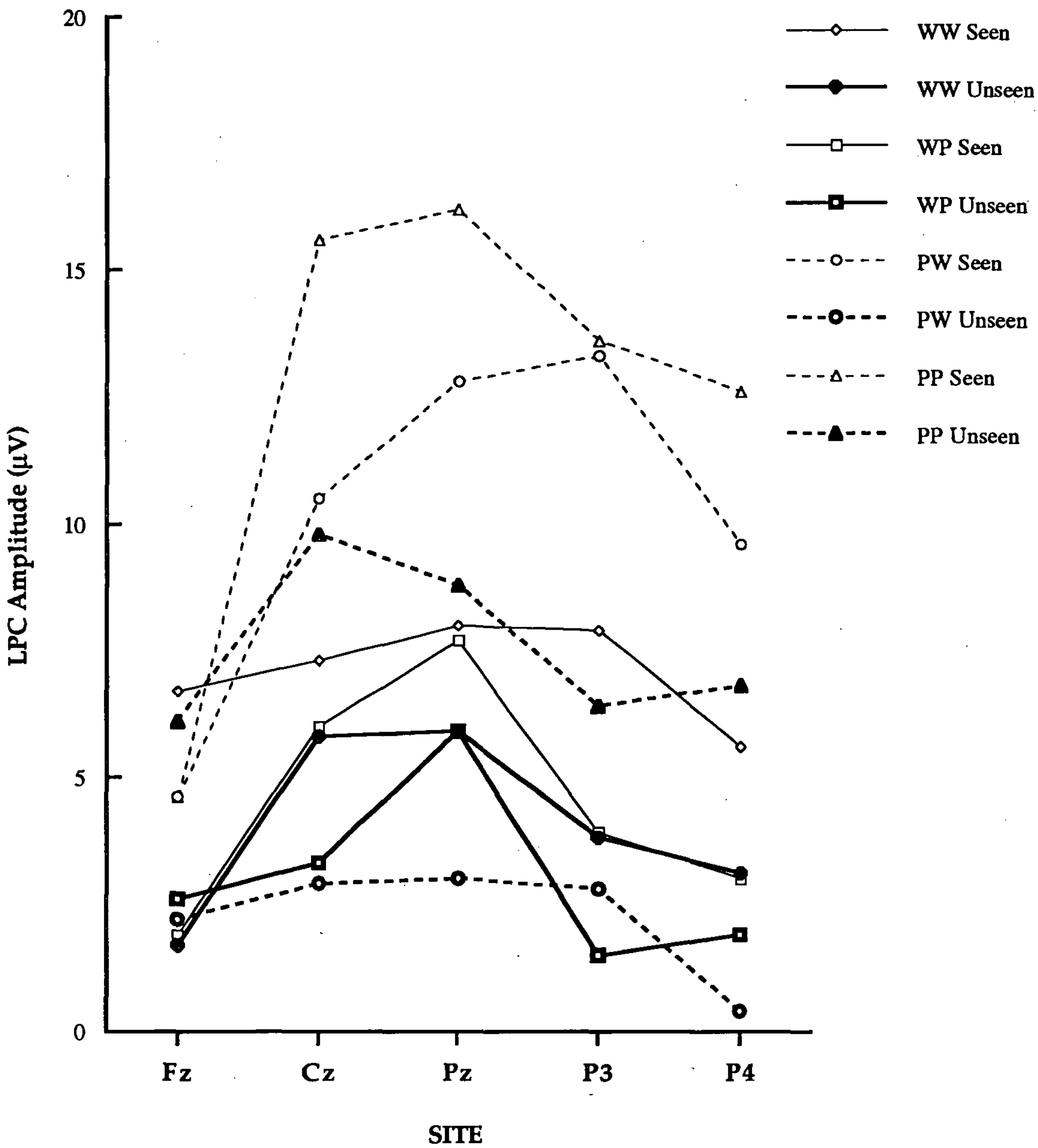

Figure F11: LPC Amplitude mean data for Seen and Unseen Stimuli for each subject group in the Memory Phase across each site.

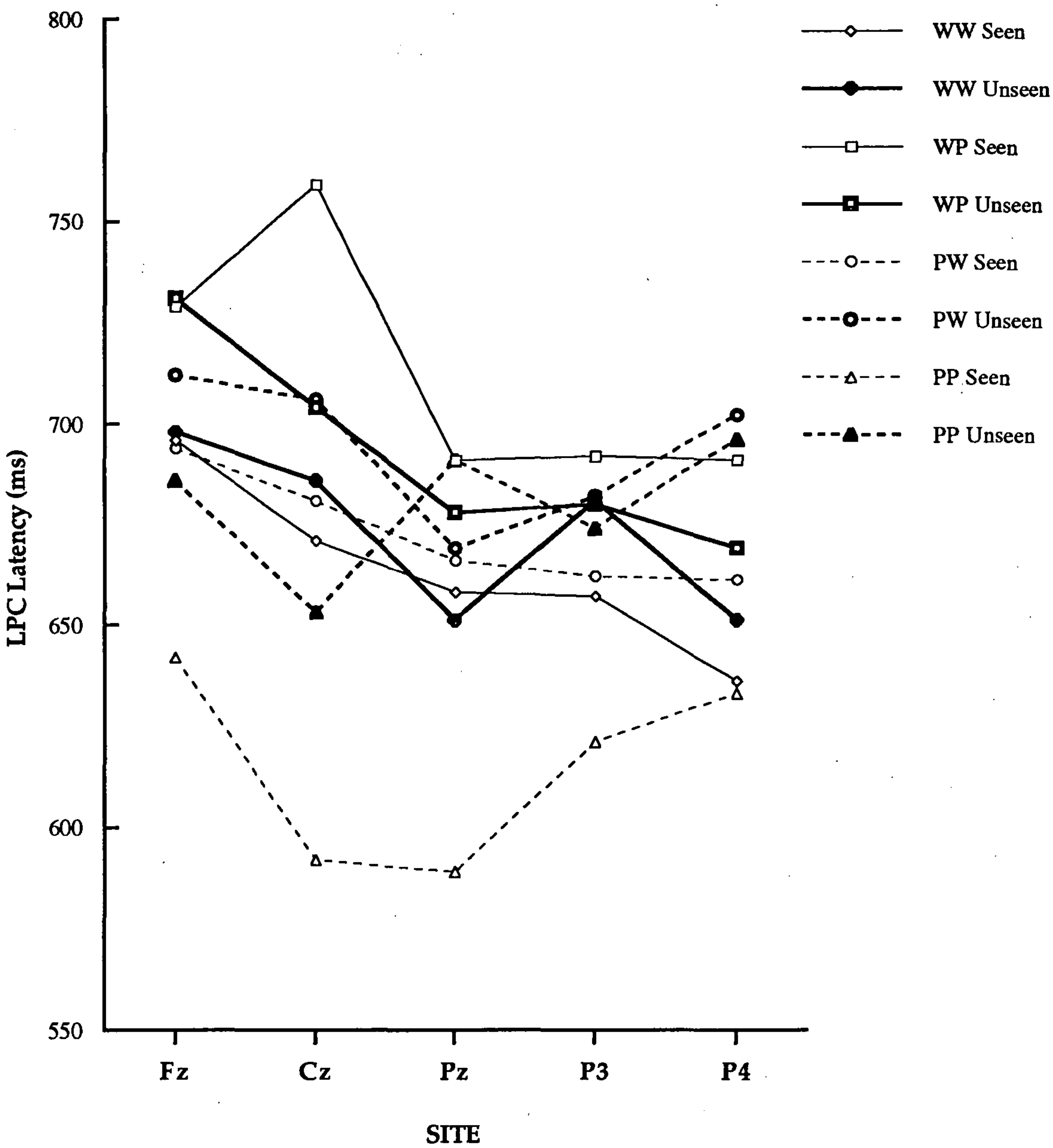

Figure F12: LPC Latency mean data for Seen and Unseen Stimuli for each subject group in the Memory Phase across each site.