To the Graduate Council:

I am submitting herewith a thesis written by Deanne Morgan Wilson entitled "P300 Auditory Evoked Potentials: Semantic Categorization in Adults." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech Pathology.

Harold A. Peterson, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

P300 AUDITORY EVOKED POTENTIALS: SEMANTIC CATEGORIZATION IN ADULTS

A Thesis Presented for the

Degree of

Master of Arts

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Deanne Morgan Wilson

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DEDICATION

This thesis is dedicated to my husband, Peter A. Wilson. Ultimately, I never would have begun this educational journey nor have finished it if it hadn't been for his encouragement and support. I don't think that there is a word in any language that could express my gratitude.

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ABSTRACT

Cortical event-related potentials (ERP) were recorded at Fz, Cz, F3, F4, P3, and P4 scalp sites in 19 normal right-handed females between the ages 20-35. All task stimuli were presented in an oddball (80-20) paradigm, with 20% of the items being infrequent targets. In the first task, subjects made push-button response choices of high and low (target) tones. In the second task, the subject listened to and identified (auditorially and visually) presented words in which target non-kitchen words occurred 20% of the time. In the third task, subjects made push-button response choices to "kitchen" and "non-kitchen" (target) items.

Comparisons were made according to P300 amplitude and latency measures. Subsequent analysis of variance for repeated measures and t-tests indicated the following results:

1. Significantly greater frontal P300 amplitude was found for semantic tasks (words tasks).

2. No significant lobe differences were found with regard to P300 amplitude for the Tones task.

2. Greater right than left amplitude was found on all tasks.

3. Greater amplitude was found for Tones as compared to both semantic (word) tasks.

4. In comparing semantic tasks, significantly greater P300 amplitude was found on Task 3 when the subject was given categorization instructions as compared with Task 2 when the subject only identified the words presented.

5. Significantly greater latency was found for semantic tasks in comparison with the Tones task.

6. No significant difference was found in latency between the two word tasks.

7. During Task 3 when the subject was given categorization instructions, greater latency was found for the frontal sites as compared to parietal sites.

Within the confines of the population studied, these results provide information in addition to current literature indicating that the right frontal areas play a major role in semantic categorization. In addition, it would also appear that latency is related to task and site, increasing as relative demands increase in crucial cortical areas.

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CHAPTER 1

Introduction

A variety of methods have been used to understand the complexity of language processing. Behavioral approaches to receptive language study have been used widely which have consisted of pen and paper tests or researcher observation of subject behavior. Over recent years, the study of language processing has begun to be carried out with more direct neuro-physiologic measurements, including magnetic resonance imaging (for neural structure and function in combination with other technology), positron emission tomography (for neural function), and evoked-response potentials (for neural function).

Evoked Response Potentials

Evoked response potentials (ERP's) are the changes which occur over roughly a 500 msec period. They are revealed by averaging electroencepha-lographic waveforms resulting from repeated presentations of the same sensory stimulus as detected by surface electrodes (Springer & Deutch, 1981). They are called "evoked response potentials" and "event related potentials" corresponding to the acronym, ERP, because they are evoked by the presented stimuli and related to the stimulus events.

Electrode Placement

Electrode placement is specified by the International 10-20 System (Jasper, 1958) which identifies up to 21 potential electrode locations on the cortex by ten and twenty percent increments of the total distances from specified reference points on the surface of the head. This system is used for placement consistency, specifying sites which would correspond to the same functional locations in individuals independent of the physical size of the head.

ERP Components

Changes in response as detected by these electrodes are directly stimulus related and emerge as positive and negative components which are generally examined with regard to the parameters of latency and amplitude (Molfese, 1978). Responses to different parameters of a stimulus are categorized according to latency epoch and associated with specific anatomical sources. For example, early responses (0-10 msec after stimulus onset) are associated with the brainstem; middle latency responses (circa 10-80 msec) are linked to the thalamus; and late (plus 80-100 msec) responses are considered cortical responses (Jacobson, 1994).

Late Responses

Late ERP responses would include the P200 (P2), N200 (N2), and the P300 (P3). The P200 is a positive wave at approximately 200 msec post-

stimulus and is part of the complex associated with stimulus encoding (Rockstroh et al., 1982). The N200 is a negative peak following the P200 and is related to acoustic and phonological properties of the eliciting stimuli (Donchin, 1984). The P300 is a positive peak which appears between 300 and 500 msec after the stimulus offset in adults and originates at the level of the cortex (Jacobson, 1994).

Location of ERP's Relative to Stimulus Delivery Mode

Because cortical processing reflects sharing of function, it is possible to obtain maximal ERP amplitudes which are distant from the corresponding active cortical regions (Allison, Wood, & McCarthy, 1986). However in general, evoked potentials are generated in the primary and secondary cortical areas of the mode of presentation and are recorded in the hemisphere in which they occur (Molfese, 1978). As an example, with a visual mode of presentation, the occipital lobe would be stimulated to a greater degree than it would be with auditory stimuli. However, the semantic value judgment of either visual or auditorially presented words would still be made primarily in the frontal lobes.

Relationship to Characteristics of the Eliciting Stimuli

In relation to specific stimuli, ERP responses are termed as either "exogenous" or "endogenous" based on whether the response is obligatory in nature. Late cortical responses (including the P200, N200 and P300) have

more latency variability and are characteristic of the eliciting signal as based on factors such as attention and task (Butcher, 1994; Hume 1984; Jacobson, G., 1994; Jacobson, J. T., 1994; Peterson, 1996). Molfese (1978) notes that the late cortical responses, i.e., those after 80-100 msec, generally may be altered by associated mental states and cognitive processes and may demonstrate significant variability with regard to task, mental state, and subject.

The P300 Late Cortical Response

Among the endogenous components, the P300 late cortical response has been described to be indicative of "special cognitive processes" (Jacobson, 1994). It is labeled "P300" because it is a positive voltage component which generally appears between 300 and 500 msec after the stimulus onset in adults. The P300 response originates at the level of the cortex (Donchin in Allison, 1984; Jacobson, 1994) in the area of the temporo-parietal association area which is between the visual, auditory, and somes-thetic systems (Friedman et al., 1977). Donchin (1984) notes that for tones the P300 component is generally largest at the parietal electrode sites.

The P300 is usually elicited by a rare, unexpected, task relevant stimulus (Donchin, 1984). Here, "task relevant" implies that the subject is paying attention to the stimulus. As Johnson & Donchin (1978) describe it, the P300 is elicited by stimuli which deliver information, superimposing a

positive voltage wave over average electrical response. The oddball paradigm is used to elicit the P300 response, and it achieves this by presenting an "odd" or infrequent number of stimuli items (e.g., 80% vs. the 20% infrequent) to which the subject's surprise response is elicited (Hall, 1992; Jacobson, 1994) . The amplitude of the P300 depends inversely on the relative presentation probability of the category of the stimulus and not the presentation probability of the individual stimulus itself (Donchin, 1984; Donchin & McCarthy, 1979). Although the P300 may be elicited on all stimuli, an increase in the subject's value of the stimuli results in increased P300 response amplitude (Friedman, 1975). The relative P300 amplitude also increases with increased task demands (Friedman, Simson, Ritter, & Rapin, 1975).

The latency of the P300 is determined by the difficulty of the discrimination task and by cognitive maturation. Regarding difficulty, McCarthy and Donchin (1981) measured latency and choice reaction time simultaneously, noting that P300 latency is related to stimulus evaluation time while relatively unrelated to response selection processes. With regard to maturation, Courchesne (1978, 1979) tracked P300 response latency in children through adults. He found that response times decreased with age and noted the waveform transition to adult latency occurred in the mid-teens. This latency is related to a subject's reaction time to the extent that he/she

employs a processing strategy (Kutas et al., 1977).

P300 responses may also be influenced by time of day, glucose levels, and body temperature (Geiser & Polich, 1990), and possibly influenced by the sex and handedness of the subject (Springer & Deutsch, 1981).

ERP's and Linguistic Research

Evoked response potentials (ERP's) have been used in cognitive and linguistic research to offer correlational information to commonly used behavioral measures--mean reaction time and the number of incorrect responses--in a semantic memory task (e.g., Allen, Iacono, & Danielson, 1992). Advances in ERP technology have made it possible to study on-going neural activity relative to language processing and lexicon acquisition (Molfese, Morris & Romski, 1990).

One method of stimuli delivery in this type of linguistic/ERP research is through the auditory channel via Auditory Evoked Potentials. This method has been used frequently to investigate the acoustic, phonologic, morphologic, semantic, syntactic, and pragmatic aspects of language, with greater focus being given to the first three (Peterson, 1996). Although notable examples have been contributed in the areas of semantics (e.g., Molfese, 1990) and syntax (e.g., Van Petten and Kutas, 1991), much remains in both of these sub-areas which could be suitably investigated with the endogenous event-related components of the averaged (ERP) waveform through the

auditory presentation of stimuli.

Because the endogenous components of the ERP are responses to characteristics of the signal stimuli, it is possible to use this method to observe neurophysiologic response to presented stimuli requiring varying degrees of complexity in information processing (Donchin, Kubovy, Kutas, Johnson, & Herning, 1973). A particularly useful endogenous component in this task is the P300.

The P300 and Linguistic Research

The P300 has been demonstrated to have particular value in the assessment of semantic categorical task processing. For example, Aragane, Tachibana, & Sugita (1995) compared the P300 measure with motor response time in a semantic discrimination (categorical) task. The P300 findings demonstrated that neural semantic categorization latencies and motor response times were significantly longer in a Parkinson's group as compared with the normal group. A disturbance in the classification and attention processes in those with Parkinson's disease was thereby demonstrated.

Other researchers (Allen et al., 1992) used the oddball paradigm (80 percent frequently occurring stimuli and 20 percent infrequently occurring stimuli) to show the correlational validity of the P300 in semantic tasks. In their task, the oddball paradigm was used to deliver rare and recognized

stimuli. They found that the P300 component of the waveform, with regard to amplitude and latency, distinguished learned from novel semantic material.

In summary, the P300 component of the ERP and the odd-ball method of stimuli delivery is a validated measure used in the investigation of semantic categorization. That is, differences in the P300 waveform are reflective of the process of semantic categorization. In that it is "task relevant," the task of semantic categorization may be evaluated by P300 amplitude and latency with consideration given to the role of selective attention while evaluating responses to the characteristics of the signal stimuli.

Based on the advantages of using the P300 ERP in the study of semantic categorization, the following study was completed. It was designed to investigate late cortical responses, particularly the P300, during an auditory semantic categorization task in a group of normal young, right-handed, female adults. As reflections of listening strategy, measures of a) the relative amplitude differences between target and non-target responses and b) differences in the response latency and amplitude were sought.

CHAPTER 2

Review of the Literature

ERP's have been used in a variety of ways to investigate language processing of infants, children, and adults. Generally, focus has been given to the perception of phonemes and the acoustic elements of language. Because this averaged electroencephalographic wave form corresponds to specific stimuli presented through a variety of modalities, it also lends itself particularly well to the investigation of lexical processing. Comparatively, ERP's have been used less often for this purpose. For this reason, this review of literature will focus on the elements of categorical perception and late auditory evoked potentials as they pertain to the neurophysiologic observation of semantic processing.

Categorical Perception

Categorical perception is based on the recognition of a boundary which makes identification and discrimination possible (Harnad, 1987). Molfese (1987) adds that this process is one where the same-sized differences between stimuli are easier to determine across categorical boundaries than within.

Phonemic Categorical Perception

With special interest in the cognitive response during categorical perception, researchers have used ERP's linguistically to examine primarily

the categorization of speech sounds. To this end, categorical perception has been demonstrated using ERP's. In a recent example, Maiste, Wiens, Hunt, Scherg, and Picton (1995) used ERP's to examine the categorical perception of speech stimuli, finding that the N2-P3 (N200-P300) complex accurately reflects the phonemic categorization of their presented speech stimuli.

Molfese (1980) examined which cue enables the subject to identify phonemes which are not contextually based. This work illustrated that it is left hemispheric processing which differentiates between phonemes and not acoustic variances which would elicit a much earlier response (100 msec post-stimulus). Regarding the phonological representation of sounds, Polich, McCarthy, Wang, and Donchin (1983) used a rhyming word task to elicit a categorical response differentiating between cortical representations.

Semantic Categorical Perception

In addition to examining the categorical perception of speech sounds, Molfese and his colleagues have also looked at the categorical perception of words. The results of this research provided information about a variety of phonemic and semantic tasks in infants through adults with varying focus on relative component amplitude, laterality, and latency of response with noted greater frontal and left hemisphere responses during this type of task (Molfese, 1977, 1985, 1989, 1990; Molfese & Betz, 1988; Molfese, Morris, & Romski, 1990).

Semantic Categorization

Word Discrimination/Identification

Known and unknown words. ERP techniques have been successful in measuring infants' discrimination of known and unknown words as demonstrated by the work of Molfese and his collaborators (Molfese et al., 1985 as discussed in Molfese & Betz, 1988; Molfese, 1989, 1990). Molfese (1989, 1990) noted that analysis of responses from frontal, temporal, and parietal areas of the left hemisphere discriminated reliably between known and unknown words in 14 and 16-month-old infants (male and female). This study made use of parent or independent observer to help determine those words which would be known or unknown. Frontal lobes and the left hemisphere were noted to have greater activity during this task.

Physical, name or categorical identity. Other researchers (Friedman, Putnam, Ritter, Hamberger, & Berman, 1992) have focused on the ability of children and adults to identify word pairs as same or different based on physical, name or categorical identity. In this group comprised of males and females ranging in age from 6-39, P300 latency increased as the stimuli became more complex.

Semantic Context/Syntactic Context

Terminal words in sentences. Among other semantic concerns, some investigators have focused on the semantic, phonologic and/or acoustic properties of terminal words in sentences as being contextually appropriate or inappropriate (Connolly, Phillips, & Forbes, 1995; Connolly, Phillips, Steward, & Brake, 1992). In drawing conclusions from these types of presentations which ranged from phonologically expected and semantically appropriate words to phonologically unexpected and semantically inappropriate words, researchers determined that the N200 reflected the acoustic/phonological processing of the terminal word while the N400 reflected cognitive/linguistic processing in context. Because the N400 is generally associated with semantic priming and/or sentence comprehension contexts its function is restricted in the study of semantic categorization. Amplitude of these peaks was found to be relative to the contextual constraint of the sentence.

P300 vs. the N400 in semantic and syntactic context. As an extension of examining context effects, Van Petten and Kutas (1991) looked at the separate contributions of syntactic and semantic context. Their findings suggest that the P300 is sensitive to syntactic/strategic constraints, and the N400 is indicative of the processing of individual words. This was noted to be especially true of the more predictable function words, but the N400 did not

identify the differences in the processing of content vs. function words.

Value

Attaching meaning or emotion. Another area of focus has been meaningful vs. meaningless and emotion laden vs. emotionless words. Attias and Pratt (1992) employed this focus in comparing the reaction times associated with meaningful vs. meaningless words and concluded that longer reaction times were associated with non-meaningful word targets and the complex task of exhaustively searching memory for lexical correlates.

A group of researchers (Wexler, Warrenburg, Schwartz, & Janer, 1992) has made particular use of laterality of response to investigate conscious vs. unconscious processing of emotion-evoking words, finding greater right hemispheric processing during these tasks and "emotion-specific" response to stimuli processes without conscious thought.

In contrast to Wexler et al., Van Strien and Morpurgo (1992) looked specifically at the role of threatening vs. non-threatening stimuli in influencing laterality of response. They found that negative emotions could alter cerebral laterality, activating the right hemisphere more than in conditions which were **not** threatening or stressful to the subject.

In relation to this evaluative semantic sense, others (Chapman, R. M., Bragdon, Chapman, J.A., & McCrary, 1977; Chapman, R. M., McCrary, Chapman, J. A., & Martin, 1980) found that connotative semantic meaning is

reflected in the ERP waveform configuration by changes in amplitude and latency. Furthermore, Molfese (1985) found the P300 waveform to be sensitive to the semantic feature "positive" vs. "negative" but found this to be true bilaterally instead of locating either one in a specific hemisphere.

Word Categorization Without Context

Within the body of ERP investigation on the semantic front, a little is noted with regard to semantic categorization independent of a sentence context.

Word pairs. Within this area, limited tasks such as word pairs have received some investigation. For example, word class tasks such as noun vs. verb (Roemer & Teyler, 1977; Marsh & Brown, 1977) or boy vs. girl names (Kutas, McCarthy, & Donchin, 1977) are likely tasks. However, longer confrontational categorization tasks with relevance to selective attention effects on late cognitive responses have not been addressed fully. Although the late evoked P300 waveform has been shown to be useful in revealing the importance of attention to task during categorical response, it is not often used to this end.

Longer confrontational categorization. In a rare example of employing an active categorization task, Wesensten and Badia (1992) used a semantic categorization task of identifying a concrete item with its category (a subordinate) as a means to determine time of day effects. In this study the

N100, P200, N400 and P600 components were recorded every two hours from 9:00 a.m. to 9:00 p.m. to illustrate changes which were accounted for by diurnal variation alone. However, they did not report data regarding the categorical perception and processing of semantic items.

Even though Molfese (1985) demonstrated that the processing of semantic categorization could be actively reflected in the differences of the P300 waveform, context (as described above) is more often the element explored. It is employed for clues into the process of lexical access or to explore the level of task difficulty in a semantic relatedness task (Bentin, Kutas, & Hillyard, 1993). In this situation, the N400 or N200 measure is used to these ends. This is done even though the N200 is more related to the acoustic or phonological properties of the stimuli and the N400 does not measure discrimination of content words as the P300 does.

Effectiveness of the P300 in longer tasks. Notably, the P300 measure may be used effectively within a longer confrontational categorization task with words which belong to the same word class and have possible common lexical features. This is substantiated by Nasman and Rosenfeld's (1992) review of the enhancement of the P300's amplitude in tasks involving between-category discrimination among high and low probability events (also known as the oddball paradigm of stimuli presentation). Their work tested the P300 measure of within-category differences, recognizing that this process

requires overall attention to stimulus presentation and serves as an index of attention activation during high and low probability events. In this task, the P300 responses were larger with the target within-category deviant stimulus items. However, this study's task of noting matching vs. deviant numerical pairs did not demonstrate clear use of linguistic functioning but rather focused on concept formation.

Lubar, Mann, Gross & Shively (1992) have addressed a longer confrontational categorical task consisting of items within a category instead of the usual word pairs task. In this study, 42 right-handed male and female children between ages 8 and 12 who were identified as learning disabled, normal, or gifted. Subjects categorized nouns in the oddball paradigm as being animal names (targets representing 20% of the stimuli). This was done by pressing a button to signify this choice and remaining motionless if a non-target noun was presented, counting the difference in motor response as negligible. These researchers concluded that P3 (P300) responses to the presented task were effective in differentiating between the three subject sub-groups on the basis of P300 amplitude and latency. P300 amplitude to target stimuli was lower in the learning disabled group as compared with the normal and gifted groups, finding this to be most true at the parietal site. Less significant differences on this point were found between the normal and gifted group. P300 responses in the disordered group were smaller in

amplitude and had a longer latency. This study begins to provide a rationale for a neurophysiological measure to be used in diagnosis and in evaluation of treatment effectiveness when used in a pre- and post-treatment design. However, other authors have noted that the maturation of the P3 (cognitive) response does not occur until mid adolescence (Peterson, 1996) and that there is no normative data for this type of task across ages. This study does not provide the needed normative data for comparison across ages.

Another group of researchers (Meador et al., 1987) studied 12 healthy adults (5 men and 7 women) from ages 19 to 48 years during a phonemic and a semantic task. The semantic categorization task included counting the number of target stimuli as the stimuli were presented at equal intervals. They found a smaller P3 amplitude during the semantic task than during the phonemic rhyming task. Unfortunately, important ERP response factors such as the variance of members of each sex was not controlled for in each sub-group. In addition this study did not extend to information about responses during differing semantic tasks.

Rationale

As illustrated by the research described above, the ERP is a viable method for acquiring neurophysiological measures of cognitive response during linguistic processing. In particular in the adult population, the P300 response, an endogenous response which reflects the informational value of

the stimulus, would be particularly useful in understanding the cortical processes involved in semantic categorization tasks which are independent of a facilitating syntactic context. This information is not adequately represented in current literature.

With regard to semantic investigation, the categorization of words independent of a facilitating syntactic context (words without a sentence context) is under-investigated. Often, treatment of adult language disorders includes a confrontational naming task without a viable means of understanding the cortical processing elements of this task. An example of a confrontational semantic categorization task would be, "These eight items are all things related to a car."

Although some (Lubar, et al., 1992; Nasman & Rosenfeld, 1992) have begun to investigate word categorization by giving the subjects the specific task, it would also be relevant to have measures of cortical processing when the task or strategy is assigned, in contrast to when it is not. In this contrast, a subject could first listen for identification of stimuli without any further instruction as to processing the information. Then the subject would be told specifically what to do. (For example, "Push the button when you hear a word which you think is a positive word.")

Certain expectations in P300 cortical response may be derived from current literature. Based on supporting literature regarding the oddball

paradigm (Johnson & Donchin, 1978), P300's were expected in all experimental tasks. Based on Friedman's work (1975) which noted an increase in value of the stimuli resulting in an increased P300 amplitude, a greater P300 response was anticipated in the second semantic task (Kitchen 2). Latency was expected to increase as the stimuli became more complex (Friedman, et al., 1992). And based on the work of Molfese and others (Molfese, 1977, 1985, 1989, 1990; Molfese & Betz, 1988; Molfese, Morris, & Romski, 1990), semantic categorization of words was expected to elicit greater frontal activity as reflected in P300 amplitude.

Purpose

The purpose of this study was to measure semantic categorization: performed without instructions in a visual and auditory odd-ball task and performed with instructions in an auditory odd-ball task with push-button responses. This was compared with tone categorization as reflected in the differences of the P300 waveform. This study's unique aspect was the combination and comparison of the presented tasks. (See Table 2-1.)

Table 2-1. Task labels/description

TASK	ABBREVIATION
Task 1: Tones & Button Response	Tones
Task 2: Identify Words	Kit. 1 (Kitchen 1)
Task 3: Categorize Words & Button Response	Kit. 2 (Kitchen 2)

Processing was studied using the cortical P300 response, allowing comparison of hemispheres and lobe activity.

The purpose of task 1 was to present tones to establish subject baseline P300 responses. The purpose of task 2 was to present the subject (in an odd-ball paradigm) with a task to listen to and identify presented words without being given an eliciting strategy and find out if she would verbally report a semantic categorization strategy and/or generate a P300 waveform response. If a P300 waveform was generated, the latency was noted.

The purpose of task 3 was to present the subject with the listening task with a specific listening strategy which was verbally given to the subject to identify items within and outside of a subordinate category and determine if a greater P300 amplitude or latency was generated. This task was held in contrast to task 2 and task 1.

Research Questions

1. The following questions regard P300 differences relative to the subject's verbal identification of a semantic categorization strategy and any associated electrophysiological P300 measures.
   A. If the subject verbally identifies a semantic categorization listening strategy in the Kitchen 1 task, is there a difference in relative P300 amplitude to the target words in the Kitchen 2 task

as compared with the Kitchen 1 task?

B. When told to only listen and identify (auditorially and visually) the words while stimuli are presented according to an odd-ball (80-20) paradigm, does the subject generate a P300 to the target/infrequent stimuli?

2. The following questions relate to location of semantic categorization response.

A. Is there a difference in P300 response according to hemispheric laterality?

B. Is there a difference in P300 response according to cortical lobe electrode placement sites (frontal lobe vs. parietal lobe)?

3. The following relates to the amount of time taken to process a categorization task.

A. Is P300 latency different for acoustic vs. semantic tasks?

CHAPTER 3

Methods

This investigation was designed to use electrophysiological means to quantify and compare the cortical processing of female, right-handed adults when presented with tones and words. Electrical responses were recorded from electrode sites which were located using the International 10-20 system (Jasper, 1958).

Subjects

After receiving permission from the University of Tennessee Committee on Research Participation, college student volunteers were recruited to participate in the study. Nineteen (19) female adults served as subjects in this study. The age range of these subjects was 20 to 35 years of age, with a mean age of 27.5. All subjects were students at the University of Tennessee in the Department of Audiology and Speech Pathology. Participating subjects were drawn from a population of volunteers who received extra credit for a departmental class in return for participation. The departmental class which issued the extra credit was not connected to any examiner or faculty member involved with this thesis research project. Subjects were not paid for their participation.

Selection Criteria

Right-handedness. Subjects were all right-handed to control for the tendency of bilateral dominance in left-handed individuals (Davis and Wada, 1974). The Edinburgh Handedness Inventory (Oldfield, 1971) was completed by all subjects before testing commenced. Criterion for selection was a laterality quotient within or above the fifth decile for right-handed individuals.

Female participants. All participants were female to control for sex differences in hemispheric laterality of response and localization of response in the site/lobe (Halliday et al., 1982).

Age. Subjects were between the ages of 18 and 35, a range chosen because evoked response potentials are predictably consistent during these ages (Peterson, 1996).

Language. These participants were native American English speakers.

Hearing sensitivity. A Beltone portable audiometer was used for screening subjects' hearing. All testing was completed in a sound treated room. Criteria were responses of 20 dB HL or less for pure tones at 1000 Hz, 2000 Hz, 4000 Hz, and 6000 Hz bilaterally (ANSI, 1989).

History. There were no self-reported neurological, cognitive, or learning deficits. Subjects were questioned about any history of neurological trauma, neurological disease, and documented or perceived educational difficulty.

Procedure

Three experimental tasks are described in the following section. They are listed (Table 3-1) with abbreviated labels to ease later identification.

Stimuli

Tones. In the first condition, a taped series of 200 high-pitch (1000 Hz) and low-pitch (500 Hz) tones in an odd-ball (80/20) randomized order were presented to establish a response baseline for each subject.

Words. During the second and third listening conditions, fifty (50) monosyllabic concrete nouns were presented. Forty (40) of the randomized words represented items which one could expect to find in a kitchen and were designated as non-targets (Table 3-2). Ten (10) monosyllabic concrete nouns which would not usually be expected in a kitchen were designated as targets (Table 3-3).

Target and non-target words were chosen carefully so that a categorical response would not be elicited merely by the similarity of the phonemic aspects of the word or by an obvious semantic relationship between the words. Instead, it was designed that the categorization of these words in the

Table 3-1. Task labels.

TASK	ABBREVIATION
Task 1: Tones & Button Response	Tones
Task 2: Identify Words	Kit. 1 (Kitchen 1)
Task 3: Categorize Words	Kit. 2 (Kitchen 2)

Table 3-2. Non-Targets.

broom	can	dish	pan	pot	jar	knife	mop
rag	plate	bowl	rack	sponge	stove	chair	stool
cloth	egg	shelf	light	door	cup	phone	ice
floor	towel	sink	bread	plant	pie	soup	clock
fridge	mug	fork	food	mat	spoon	juice	cheese

Table 3-3. Targets.

rope	saw	bike	rake	couch
lamp	sled	drill	bed	skis

"Identify Words" task (Kit. 1) would necessarily occur by the subject applying a strategy for categorization (putting the items in one designation or another).

The words were randomized, recorded, digitized and stored in two randomized lists on a Macintosh computer using SoundEdit 16 (1994) software. These words were spoken by a female speaker in General American Dialect, and the duration of the words was controlled by the SoundEdit 16 (1994) computer program so that the presentation of each word was approximately equal in length without exceeding 700 msec.

Auditory and visual stimuli. In an attempt to make all of the words relatively close in duration, some words were truncated. Pilot studies revealed that not all subjects correctly identified all words presented through the auditory mode. To insure that all of the words were correctly identified, a randomized list of the stimulus words was supplied during the "Identify Words" task (Kit. 1). Thus, this (Kit. 1) presentation used both auditory and visual stimuli.

In the "Categorize Words" task (Kit. 2), these same stimulus words were then placed in a different random order and presented by auditory stimuli only. Pilot subject data revealed no significant response latency difference between the Kit. 1 and Kit. 2 tasks. In addition, pilot subject data also revealed a constancy of P300 amplitudes between subjects who received visual stimuli in Kit. 1 and subjects who were able to identify all

words without assistance during this task. This indicated no benefit from the additional visual stimuli in the Kit. 1 task other than of word identification.

Trial set. The above stimuli were transferred to cassette tapes for presentation. Evoked responses to 40 infrequent (target) and 160 frequent (non-target) stimuli (80/20 odd-ball paradigm) comprised a trial set for each condition. The inter-stimulus interval (isi) varied between 2 and 4 seconds.

Subject Initiation

Each subject received an explanation of the study, including a brief overview of electrophysiological testing procedures. The subject was told that the study's purpose was to examine the nature of how the brain processes words and tones. She was then asked the following questions to verify selection requirements:

> "Is American English your native language? Have you ever suffered a blow to the head? Have you any known neurological, cognitive, or learning disorder?"

If the subject qualified, given these screening procedures, written consent was obtained. If the subject consented to participate, a hearing screening was given before experimental data was collected.

Stimulus Presentation

An oddball target detection paradigm was used during the delivery of stimuli with an infrequent (target) stimulus probability of 20 percent.

Tones. In the first experimental condition, a low-pitch 500 Hz tone was used as the infrequent stimulus (20 percent occurrence) and a high-pitch 1000 Hz tone was used as the frequent stimulus (80 percent occurrence) in a randomized series of 200 stimuli.

Words. In the Kit. 1 and Kit. 2 tasks, the "targets" identified in Table 3-3 were used as the infrequent condition (20), and the frequent condition (80) consisted of the "non-targets" noted in Table 3-2. In these tasks, each stimulus word was repeated four times in a randomized list for a total of 200 words.

Instrumentation

Data Recording. Responses were recorded through type F-E5 GH (Grass) 6 mm surface electrodes with protected leads. Electrode sites were determined using the International 10-20 (Jasper, 1958) system. Electrodes were secured with surgical tape on the scalp at the abraded sites at frontal zenith (Fz), central zenith (Cz), left and right parietal (P3/P4), and left and right frontal (F3/F4), with linked reference electrodes on each ear and a forehead ground. Impedance was measured to be under 5K ohms. The electrodes were connected to Grass P-511K Amplifiers via protected SAFELEAD receptacles. The stimulus recording window began 100 msec pre-stimulus and lasted until 700 msec post-stimulus.

Stimuli delivery. Stimuli were delivered at approximately 70 dB HL at ear level via overhead speaker as measured by a Realistic sound level meter. Stimuli was delivered using a JVC TD-W303 Stereo cassette deck. The subject sat in a comfortable chair inside a sound-treated room with all physical movement subdued during the three tasks (except that which was directly associated to the given task).

Subject Instructions

Subjects were notified that a brief rest period would be provided between each of these task sets. Total stimulus presentation time was about 45 minutes. Total session time was approximately 90 minutes which included short breaks, electrode placement, set-up, and clean-up time.

During all three listening conditions, subjects were asked to watch a series of slides which simulated the movement of a minute hand of a clock which was projected on the wall directly in front of them. The slide sequence was highly predictable. It was included to discourage bodily movement, to help keep the head and eyes as still as possible, and to minimize the question of cognitive activity.

Tones & button response. In the first task, "Tones & Button Response" (Tones), the subject was presented with a series of 200 high and low-pitch tones in an odd-ball (80/20) randomized order. She was asked to push a button on the right when she heard a low-pitch (infrequent) tone and a

button on the left when she heard a high-pitch (frequent) tone (Friedman, Simson, Ritter, & Rapin, 1975). The inter-stimulus interval (isi) varied between two and four seconds to reduce the prediction and anticipation of stimuli. This listening task provided a relative base for comparison with the experimental listening conditions: task 2 "Identify Words," and task 3, "Categorize Words.".

Identify words. In the second listening task, "Identify Words" (Kit. 1), the subject was told to "listen carefully and try to remember the words you hear as you silently look at the words on this sheet." As previously described, a list of words (visual stimuli) was included to insure each word's identification. Fifty (50) words were presented in four randomized lists for a total of 200 words. A variable 2 to 4 sec isi was used. This task lasted about 10 minutes.

The subject was then asked, "What did you notice, if anything, about the words that you have just heard?" Responses were recorded. The intent was to determine if the subject employed a strategy for categorizing the words in this listening task. The subject was then told, "The words should have all been familiar objects found in or around a house. Some of the objects named would reasonably be expected to be found in a kitchen and others would not usually be expected to be found in a kitchen."

Categorize words. Before the third listening condition called "Categorize Words," the subject was instructed to "listen closely, and push the button on the right (to be identified for the subject) when you hear a word for an object NOT found in a kitchen and the button on the left (to be identified for the subject) for an object reasonably found in a kitchen." Push-button responses were recorded. A 90 percent target agreement score was imposed, and this excluded subject data if the subject's category choices did not agree with target data 90% of the time. The same 200 words as in Kit. 1 were presented, but they were presented in a different randomized order with a variable isi ranging from 2 to 4 sec.

In one sense, both the intended "target" and the intended "non-target" words were being targeted by instructions to "push the button." This instruction would be expected to reduce the amplitude difference between the frequent (non-target) and the infrequent (target) words. The prime difference expected between the "Identify Words" and the "Categorize Words" listening task is in greater amplitude of the P300 response due to the assigned strategy.

If the subject reported a strategy for categorizing words in the "Identify Words" task, then less differentiation in amplitude or laterality of the P3 (P300) (categorical) response between task two and task three ("Categorize

Words") was expected. If the subject made no verbal report of a semantic processing strategy in task two (Kit. 1), no relative laterality of response (left versus right hemisphere) and no differentiating P3 response was expected.

Data Analysis

Storage. After stimulus delivery and procedure completion, electrode impedance was measured again. the evoked response potentials were filtered through a Wave-Tek 852 Hi/Lo Filter and Analog to Digital Converter (ADB12.16 Metaresearch).

Collection and averaging. Data were collected and analyzed in a Macintosh personal computer using an EPACS (Molfese, 1988) software program which also was used to average the responses to the frequent and infrequent stimuli in each condition.

P300 identification. The P300 component was visually inspected and identified across sites for consistency (waveform over time). It was identified as the first, consistent, largest positive peak which appeared later than 250 msec after stimulus offset. In the oddball paradigm when a categorical response is noted, the P300 was defined as the highest consistent peak from approximately 250 to 400 msec after the stimulus offset.

A data point was recorded at each of the six collection sites for frequent (non-target) and infrequent (target) conditions by recording the amplitude (Appendix A) and latency (Appendix B) of the data point. Ampli-

tudes were measured based on a Baseline to Peak (BTP) reading from a baseline condition of 100 msec prior to the onset of the word to the identified P300 peak.

CHAPTER 4

Results

Data Sets

Data Points

A data point was recorded at each of the six collection sites for frequent (non-target) and infrequent (target) conditions across the three tasks. The P300 peak was identified according to the operational definition set forth in the methods section. Amplitudes were measured based on a Baseline to Peak (BTP) reading from a baseline condition of 100 msec prior to the onset of the word to the identified P300 peak. Amplitude values reported (Appendix A) are relative point values. Using this method, 30 relative points are the calibrated equivalent of one microvolt (μV). See figure 4-1 for an example of this identification method which uses a cursor to mark the identified peak. The recording window included a 100 msec pre-stimulus period and 700 msec of post-stimulus onset time.

Intrajudge and Interjudge Reliability

Intrajudge. Each P300 data point was scored twice by the student experimenter according to the operational definition set forth in the methods section. An intrajudge agreement of 95% was reached. Because discrepancies appeared to be notation errors (e.g., a transposed number), all

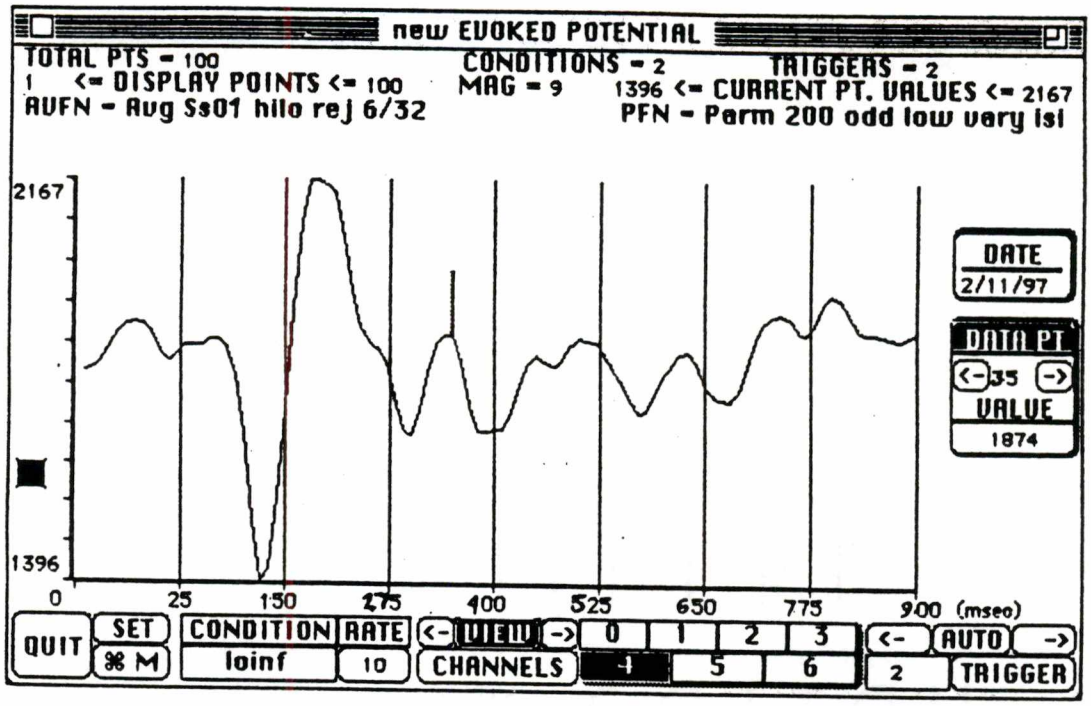


Figure 4-1: Example of P300 identification.

of them were submitted to the major faculty advisor for verification.

Interjudge. The student experimenter and the major faculty advisor performed the interjudge reliability procedure. Seventeen percent of the data was re-scored for interjudge reliability. For this purpose, the Fz and Cz data points for the frequent (non-target) and infrequent (target) conditions were scored for each task (6 amplitude values and 6 latency values for each subject). An interjudge agreement of 100% was achieved.

From these readings, two data sets were derived: amplitude readings (Appendix A) and latency readings (Appendix B). Statistical analysis procedures were performed on both sets.

Statistical Analysis

Tests of Normality

Amplitude and latency data were log transformed to produce a more normal curve (Lubar et al., 1992). Analysis of this data with the Kolmogorov-Smirnov and also the Shapiro-Wilk tests of normality statistics revealed that all sets of data were normally distributed. As a result, a parametric analysis of variance for repeated measures (ANOVA) was used to analyze data variance. The same data (natural logs derived of the raw data) was used for all statistical testing.

Variance Tests

A 3-by-2-by-6 (3 tasks, 2 conditions, 6 electrode sites) ANOVA for

repeated measures was completed for each data set, using the .05 level of confidence for the criterion of significance.

ANOVA For Amplitude Data Set

Mauchly's Test of Sphericity revealed that sphericity could not be assumed. Therefore, the Huynh-Feldt epsilon adjustment was made. Results of the ANOVA for amplitude data, presented in Table 4-1, yielded statistically significant findings for the effects of task ($p = .005$), frequency (frequent vs. infrequent) ($p = .000$) and site ($p = .000$). Two-way interactions were found for task*frequency ($p = .000$) and task*site ($p = .002$).

Paired t-tests For P300 Amplitude Data Set

To further identify specific sources of variance, paired t-tests were conducted on the effects and interactions revealed by the ANOVA. (See Table 4-2.) The .017 level of confidence was used as the criterion for significance in these t-tests as determined by performing the Bonferroni correction. This correction was determined according to the number of tests performed to control the experiment-wise error rate.

Task and condition (frequency). In investigating the interaction between task and frequency, paired t-tests were performed for frequent vs. infrequent (target) conditions for each task. Differences in amplitude were found to be significant between frequent and infrequent conditions on all tasks, indicating the presence of significant P300 responses for each of the

Table 4-1. Analysis of variance for P300 peak amplitudes.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
TASK	5.184 E-02	1.227	4.226 E-02	8.790	0.005	.328
Error (Task)	0.106	22.083	4.807 E-03			
Freq.	0.106	1.000	0.106	158.878	0.000	.898
Error (Freq)	1.204 E-02	18.000	6.688 E-04			
Site	7.810 E-02	2.043	3.824 E-02	34.196	0.000	.655
Error (Site)	4.111 E-02	36.765	1.118 E-03			
TASK*FREQ	3.560 E-02	2.000	1.780 E-02	36.469	0.000	.670
Error (TASK*FREQ)	1.757 E-02	36.000	4.881 E-04			
TASK*SITE	2.330 E-02	2.165	1.076 E-02	7.376	0.002	.291
Error (TASK*SITE)	5.685 E-02	38.961	1.459 E-03			
FREQ*SITE	1.234 E-03	3.081	4.005 E-04	2.228	0.094	.110
Error (FREQ*SITE)	9.969 E-03	55.452	1.798 E-04			
TASK*FREQ*SITE	2.115 E-03	5.595	3.780 E-04	1.783	0.115	.090
Error (TASK*FREQ* SITE)	2.136 E-02	100.716	2.120 E-04			

Table 4-2. t-tests for paired samples: amplitude data.

Effect	Variables*	Means	t-value	df	1-tailed sig.
TASK*FREQ	TONES:INFR TONES:FR	7.6086 7.5638	11.12	18	.000
	KIT1:INFR KIT1:FR	7.5710 7.5602	5.34	18	.000
	KIT 2: INFR KIT2: FR	7.5901 7.5710	6.56	18	.000
	TONES:INFR KIT 1: INFR	7.6086 7.5710	5.09	18	.000
	TONES:INFR KIT2:INFR	7.6086 7.5901	2.56	18	.010
	KIT 2: INFR KIT 1:INFR	7.5901 7.5710	6.42	18	.000
TASK*SITE	TONES:FL TONES:PL	7.5879 7.5919	-.060	18	.2785
	KIT 1: FL KIT 1: PL	7.5760 7.5542	9.76	18	.000
	KIT 2: FL KIT 2: PL	7.5919 7.5691	5.84	18	.000
	TONES:RIGHT TONES:LEFT	7.5971 7.5816	6.01	18	.000
	KIT 1:RIGHT KIT 1: LEFT	7.5715 7.5586	10.47	18	.000
	KIT 2:RIGHT KIT 2:LEFT	7.5879 7.5741	7.48	18	.000

***Variable Abbreviations:**
INFR = Infrequent
FR = Frequent
FL = Frontal Lobe Sites
PL = Parietal Lobe Sites

three experimental tasks. Significantly greater amplitudes were noted in the infrequent condition of each task. The paired samples t-test for the Tones task revealed a t-value of 11.12 ($p = .000$), demonstrating the infrequent condition to be significantly greater in amplitude than the frequent condition. The paired samples t-test for the Kitchen 1 task revealed a t-value of 5.34 ($p = .000$), also demonstrating the infrequent condition to be significantly greater in amplitude than the frequent condition. The paired samples t-test for the Kitchen 2 task revealed a t-value of 6.56 ($p = .000$), again with the infrequent condition being significantly greater in amplitude than the frequent condition.

Also, in the pursuit of investigating the interaction between task and frequency, paired t-tests were performed comparing infrequent conditions of the tasks. The paired samples t-test, comparing the infrequent condition of the Tones task and the Kitchen 1 task, revealed a t-value of 5.09 ($p = .000$), which showed that the amplitude of the Tones task to be significantly greater than that of the Kitchen 1 task. The paired samples t-test comparing the infrequent condition of the Tones task and the Kitchen 2 task revealed a t-value of 2.56 ($p = .010$). The amplitude of the P300 for the Tones task was significantly greater than that of the Kitchen 2 task. The paired samples t-test comparing the infrequent condition of the Kitchen 2 task and the Kitchen 1 task revealed a t-value of 6.42 ($p = .000$). The amplitude of the P300 for the

Kitchen 2 task was significantly greater than that of the Kitchen 1 task.

Task and site. In clarifying the interaction between task and site, paired t-tests were performed on frontal lobe sites versus parietal lobes sites for each task. Significance was found in two of the three tests, demonstrating significantly greater amplitude readings in frontal lobe sites during semantic tasks but not during the Tones task. The paired samples t-test for the Tones task did not reveal significant differences (t-value = -.60; p = .2785), indicating no advantage for parietal vs. frontal lobe on that task. The paired samples t-test for the Kitchen 1 task revealed a t-value of 9.76 (p = .000), demonstrating significantly greater amplitudes in the frontal electrode sites for that task. The paired samples t-test for the Kitchen 2 task revealed a t-value of 5.84 (p = .000), demonstrating a significantly greater amplitude in the frontal electrode sites for that task.

Also, with reference to the interaction between task vs. site on the P300 amplitude data, paired t-tests were performed on right hemisphere versus left hemisphere sites for each task. Significance was found in all tests, demonstrating a greater amplitude at right hemisphere electrode sites for each test. The paired samples t-tests rendered the following results: a. Tones task with a t-value of 6.01 (p = .000), b. Kitchen 1 task with a t-value of 10.47 (p = .000); and c. Kitchen 2 task with a t-value of 7.48 (p = .000).

Amplitude Results

It is noted that a P300 was elicited during the target condition of each task. Also, the Tones task rendered greater P300 amplitudes than both Kitchen tasks. It was also found that the Kitchen 2 task P300 responses were significantly greater in amplitude than the Kitchen 1 task P300 responses.

In that all subjects verbally reported a listening strategy during the Kitchen 1 task, it is concluded that the amplitude is heightened by providing a stimuli-relevant listening strategy to the subject as was done in the Kitchen 2 task.

Strategy. The presence of the P300 during the Kitchen 1 task to infrequent (target) stimuli appears to be related to the presence of a reported strategy in all cases. That is, all subjects were looking for patterns in the presented stimuli. In essence, the P300 is a utilizable metric for observing the application of semantic categorization strategy in female adults.

Site. Regarding location of the semantic categorization response, greater P300 amplitudes were observed at right hemisphere sites. In addition, greater P300 amplitudes were observed at frontal lobe sites for semantic tasks but not during the Tones task. In fact, during the Tones task there was no significant lobe differences with regard to P300 amplitude.

ANOVA For Latency Data Set

Again, Mauchly's Test of Sphericity revealed that sphericity could not be assumed. As in the amplitude ANOVA, the Huynh-Feldt epsilon adjustment was made. Results of the ANOVA for latency data, presented in Table 4-3, yielded statistically significant findings for the effects of task ($p = .000$). A two-way interaction was found for task*site ($p = .000$). The .05 level of confidence was selected for the criterion of significance.

Paired t-tests For P300 Latency Data Set

To further identify specific sources of variance, paired t-tests were conducted on the effects and interactions revealed by the ANOVA. (See Table 4-4.) Using the Bonferroni correction procedure to control the experiment-wise error rate, the .017 level of confidence was selected as the criterion of significance in these t-tests.

Task. In clarifying the effect of task, paired t-tests were performed which compared tasks and were inclusive of all sites. Differences in latency were found to be significant in two of the three comparisons, indicating a relationship between task change and latency. Significantly greater latency was noted for the Kitchen 1 task as compared with the Tones task (t-value 29.33; $p = .000$). Likewise, significantly greater latency was noted for the Kitchen 2 task as compared with the Tones task (t-value 55.25; $p = .000$).

Table 4-3. Analysis of variance for P300 peak latency.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
TASK	117.884	1.405	83.886	664.782	.000	.974
Error (Task)	3.191	25.287	.126			
Freq	4.099 E-02	1.000	4.099 E-02	.533	.475	.029
Error (Freq)	1.385	18.000	7.693 E-02			
Site	9.750 E-02	1.610	6.057 E-02	2.694	.094	.130
Error (Site)	.651	28.976	2.248 E-02			
TASK*FREQ	.233	1.936	.120	1.431	.253	.074
Error (TASK*FREQ)	2.927	34.842	8.402 E-02			
TASK*SITE	.593	3.847	.154	8.727	.000	.327
Error (TASK*SITE)	1.223	69.244	1.766 E-02			
FREQ*SITE	1.705 E-02	1.804	9.452 E-03	.703	.489	.038
Error (FREQ*SITE)	.437	32.474	1.345 E-02			
TASK*FREQ*SITE	6.378 E-02	3.638	1.753 E-02	1.160	.336	.061
Error (TASK*FREQ*SITE)	.990	65.492	1.512 E-02			

Table 4-4. t-tests for paired samples: latency data.

Effect	Variables*	Means	t-value	df	1-tailed sig.
TASK*SITE	KIT 1:SITE TONES:SITE	6.7065 5.8277	29.33	18	.000
	KIT 2: SITE TONES:SITE	6.7099 5.8277	55.25	18	.000
	KIT 2:SITE KIT 1:SITE	6.7099 6.7065	-.10	18	.461
	TONES:FL TONES:PL	5.8255 5.8306	-.29	18	.386
	KIT 1: FL KIT 1:PL	6.6948 6.7282	-1.26	18	.111
	KIT 2:FL KIT 2:PL	6.7577 6.6402	4.65	18	.000

***Variable Abbreviations:** **FL = Frontal Lobe Sites**
PL = Parietal Lobe Sites

However, no significant difference was found between the Kitchen 1 task and the Kitchen 2 task (t-value -.10; p = .461). These significant findings illustrate the increased processing associated with semantic categorization as compared with the categorical processing of tones.

Task and site. Pursuant of the interaction between task and site, paired t-tests were performed comparing frontal and parietal lobe response latencies for each task (FL = frontal lobe sites; PL = parietal lobe sites). Significance was found on only one of the three tests conducted. The paired samples t-test comparing frontal lobe site latencies to parietal lobe site latencies in the Tones task and the Kitchen 1 task did not find significant differences (Tones: t-value = -.29; p = .386. Kitchen 1: t-value = -1.26; p = .111). In contrast, significant differences were found in comparing the frontal lobe site latencies with the parietal lobe latencies in the Kitchen 2 task (t-value = 4.65; p = .000). Therefore, site was relevant to task during the more demanding semantic categorization task.

Latency Results

Two major findings are related to latency. First, P300 latency was significantly greater during the semantic tasks than it was during the tones task. Secondly, a significantly greater P300 latency was noted in the frontal lobe sites only during the last and most demanding semantic categorization

task. From this, latency would appear to be related to task and site, increasing as relative demands increase in crucial cortical areas.

CHAPTER 5

Discussion

In the present study, the finding that the amplitude of the P300 increased during the Kitchen 2 task as compared with the Kitchen 1 task as was expected is in keeping with Friedman, Simson, Ritter & Rapin's (1975) study in which they concluded that the P300 amplitude increases with increased task demands. Because all subjects reported a listening strategy during the Kitchen 1 task, it is concluded that the P300 amplitude is increased in semantic categorization tasks by providing a stimuli-relevant listening strategy to the subject as was done in the Kitchen 2 task.

Stated differently, a greater task demand in the Kitchen 2 task was the resolving of a greater uncertainty or the choosing of category members rather than simply identifying them. This was measured in increased amplitude in the Kitchen 2 task as compared with the Kitchen 1 task (identification only). Responses during a graduated sequence of semantic tasks should be investigated to further test this.

The overall greater amplitude of the P300 during the Tones task as compared with the semantic tasks does not bear out this notion. However, the presence of greater amplitude in the P300's for Tones as compared with the P300's for Kitchen 1 and Kitchen 2 could be due to the fact that the subject is able to be more sure of the odd tone. That is, the tone choice is

high vs. low, and this choice is simpler. In this way, greater confidence may equate to greater amplitude. The fact that some subjects made errors in the identification of target words in the Kitchen 2 task according to their push-button responses suggests less confidence and therefore reduced amplitude.

It was expected that subjects would produce a P300 response in the infrequent (target) condition during the Kitchen 1 task even though the task was to only identify the words. As active listeners, adults with normal language abilities have learned strategies to help memory which would include accessing categorized information for retrieval. The Kitchen 1 task was expected to demonstrate this by eliciting a categorical P300 response during the presentation of the infrequent, non-categorical (target) stimuli. In fact, the P300 was elicited during the target condition of each task, including those in which categorical members could not be transparently identified (in Kit. 1 and Kit. 2).

This elicitation of the P300 in the manner used is this study provides support for the utility of categorical targets and non-targets in a semantic task, a designation that depends solely on category membership. Kitchen 1 and Kitchen 2 semantic tasks used this concept of category ambiguity in a longer confrontational categorization tasks. Also, support was provided for the use of the oddball paradigm in this extended semantic categorization mode. This finding was an extension of Donchin's (1984) which noted that

the P300 is dependent on the probability of the category of the stimulus and not the individual stimulus.

Responses to the tone stimuli were expected to elicit a more parietal response (Corchesne, 1979). This expectation was not supported in that there was no significant difference in frontal vs. parietal lobes for Tones. However, subjects could have inferred that they would be making decisions about tones and words from the initial subject instructions which may have affected these results, adding more value to the categorization of tones.

As Corchesne (1979) discovered, the "more difficult to categorize" stimulus elicited more of a frontal response. It was this information and that of Molfese and colleagues (Molfese, 1977, 1985, 1989, 1990; Molfese & Betz, 1988; Molfese, Morris, & Romski, 1990) on which it had been predicted that a greater frontal response would be elicited during the semantic conditions. This expectation was substantiated by the significantly greater frontal readings during the semantic tasks.

Hemispheric processing of Tones was expected to appear mostly in the left hemisphere, as was the processing of words. This was predicted by much of the existing literature relative to ERP's as pointed out in the introduction of this document. In addition, a PET study noted that semantic categorization may induce more of a left cortical activation (Wood, Taylor, Penny, & Stump, 1980). However, the present study's results are more in keeping with

work which looks at a subject's application of value to the stimulus. Although the literature is not conclusive, the findings in this study would tend to agree with those that found greater processing in the right hemisphere (signified by greater P300 amplitudes) of stimuli which are **not** threatening or stressful to the subject (Van Strien & Morpurgo, 1992). In this way, it may be the value assigned to the task which elicits activity in specific cortical areas.

According to McCarthy & Donchin's (1981) work, it was expected that P300 latency would be significantly greater during the semantic tasks than it was during the tones task due to the relative difficulty of these task. This expectation was supported. Significantly longer latencies in the semantic tasks as compared with the Tones tasks were demonstrated.

Further, a significantly greater P300 latency in the frontal lobe sites (as above in relation to task difficulty) was found during the last and most demanding semantic categorization task. This supports the notion that latency appears to be related to task difficulty and the site(s) in which the primary processing occurs, increasing with a relative increase in demands in crucial cortical areas. Although significance was not found in the difference in latency between the frontal lobe sites and parietal lobe sites in the Kitchen 1 task ($p = .111$), frontal responses were later than parietal responses. If the sample size had been larger, significance may have been demonstrated further illustrating that latency is related to task difficulty in cortical areas

linked to specific tasks.

Within the confines of the population studied, these results provide additive information to current literature indicating that the right frontal areas play a major role in semantic categorization. In addition, it would also appear that latency is related to task and site, increasing as relative demands increase in crucial cortical areas.

In conclusion, this study supports the use of the P300 in the oddball paradigm as a viable metric of semantic categorization, though researchers should be cautious in the application of their data to the general population. Further study is needed to establish the reliability of these data with regard to the population used in this study as well as younger and older populations of both sexes. With the establishment of normative data for more populations, these results may suggest a practical clinical value in the measurement of post-morbid patients' cortical functioning during semantic categorization tasks. If used as a pre-treatment measure and post-treatment measure, cognitive reorganization may be more directly measured and observed as Neville (1980) has done with less demanding tasks.

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APPENDICES

APPENDIX A

RAW DATA FOR INDIVIDUAL SUBJECTS:

P300 AMPLITUDE

SUBJECT RAW DATA
POINT TO POINT MEASURES: P300 AMPLITUDE

	Tones:F4 Fr.	Tones: Fz Fr.	Tones: P4 Fr.	Tones: F3 Fr.	Tones: Cz Fr.	Tones: P3 Fr.
Ss 1	1912	1912	1917	1927	1833	1878
Ss 2	2011	1995	1957	2016	1914	1891
Ss 3	1869	1869	1912	1838	1835	1902
Ss 4	1976	1965	1947	1969	1876	1917
Ss 5	1881	1871	1891	1904	1809	1862
Ss 6	1916	1893	1923	1887	1844	1865
Ss 7	1913	1964	1983	1920	1956	1934
Ss 8	1976	1959	2045	1934	1940	1944
Ss 9	1912	1905	1920	1886	1851	1888
Ss 10	2013	2020	2002	1986	2018	1949
Ss 11	2015	1972	1951	2006	1873	1892
Ss 12	1898	1913	1997	1910	1968	1984
Ss 13	1920	1900	1962	1901	1866	1944
Ss 14	2029	2066	2068	2055	1981	2016
Ss 15	2024	2029	1980	2036	1896	1931
Ss 16	1862	1821	1911	1839	1852	1880
Ss 17	1909	1869	1875	1905	1841	1826
Ss 18	1883	1869	1949	1868	1884	1925
Ss 19	1974	1951	1976	1943	1909	1898

SUBJECT RAW DATA
POINT TO POINT MEASURES: P300 AMPLITUDE

	Tones: F4 Inf.	Tones: Fz Inf.	Tones: P4 Inf.	Tones: F3 Inf.	Tones: Cz Inf.	Tones: P3 Inf.
Ss 1	1948	1941	1963	1965	1874	1914
Ss 2	2098	2138	2103	2146	2021	2060
Ss 3	1941	1971	2027	1864	1928	2004
Ss 4	2035	2044	2105	2045	1968	2038
Ss 5	1970	2005	2003	1967	1955	1958
Ss 6	1971	1943	1971	1932	1886	1939
Ss 7	2021	2042	2158	1958	2061	2079
Ss 8	2079	2121	2199	2059	2140	2015
Ss 9	1942	1948	2038	1904	1909	1979
Ss 10	2073	2065	2089	2050	2073	2036
Ss 11	2135	2130	2067	2129	1999	1996
Ss 12	1961	1994	2149	1966	2133	2190
Ss 13	1939	1914	1927	1917	1857	1910
Ss 14	2072	2107	2241	2097	2127	2159
Ss 15	2138	2184	2085	2184	1999	2014
Ss 16	1967	1976	2018	1913	1954	1942
Ss 17	1992	1959	1961	1956	1876	1860
Ss 18	1989	1989	1996	1990	1998	2047
Ss 19	2046	2041	2065	2001	2037	1982

SUBJECT RAW DATA
POINT TO POINT MEASURES: P300 AMPLITUDE

	Kit. 1: F4 Fr.	Kit. 1: Fz Fr.	Kit. 1: P4 Fr.	Kit. 1: F3 Fr.	Kit. 1: Cz Fr.	Kit. 1: P3 Fr.	Kit. 1: F4 Inf.
Ss 1	1993	1996	1937	2006	1940	1888	1961
Ss 2	1963	1958	1956	1972	1881	1895	2012
Ss 3	1943	1953	1933	1902	1921	1872	1925
Ss 4	1930	1925	1905	1924	1899	1876	1954
Ss 5	1901	1906	1880	1888	1895	1857	1911
Ss 6	1918	1907	1896	1897	1882	1875	1944
Ss 7	1915	1978	1872	1909	1896	1843	1911
Ss 8	1943	1944	1914	1928	1907	1879	1954
Ss 9	1939	1939	1892	1927	1911	1860	1960
Ss 10	1912	1906	1894	1921	1882	1835	1922
Ss 11	1979	1972	1926	1973	1927	1884	2042
Ss 12	2000	1987	1931	1996	1921	1897	2024
Ss 13	1845	1937	1935	1940	1882	1894	1965
Ss 14	1968	1958	1937	1960	1884	1900	2010
Ss 15	2004	2013	2001	1994	1945	1932	2015
Ss 16	1923	1891	1901	1896	1918	1855	1938
Ss 17	1972	1936	1922	1957	1926	1881	1956
Ss 18	1921	1891	1915	1919	1896	1873	1937
Ss 19	1929	1900	1919	1908	1898	1855	1965

SUBJECT RAW DATA
POINT TO POINT MEASURES: P300 AMPLITUDE

	Kit. 1: Fz Inf.	Kit. 1: P4 Inf.	Kit. 1: F3 Inf.	Kit. 1: Cz Inf.	Kit. 1: P3 Inf.	Kit. 2: F4 Fr.
Ss 1	1963	1947	1978	1907	1924	1930
Ss 2	1997	1982	2007	1903	1909	2017
Ss 3	1963	1921	1936	1926	1874	1938
Ss 4	1939	1925	1923	1912	1883	1975
Ss 5	1912	1897	1884	1920	1863	1913
Ss 6	1931	1926	1933	1900	1854	1915
Ss 7	1911	1912	1922	1903	1836	1940
Ss 8	1947	1947	1959	1908	1903	1930
Ss 9	1955	1931	1947	1931	1912	1937
Ss 10	1918	1907	1956	1899	1887	1956
Ss 11	2005	1945	2020	1919	1926	1989
Ss 12	2018	1998	2050	1938	1941	2078
Ss 13	1955	1964	1936	1915	1919	1961
Ss 14	1989	1963	1972	1915	1906	2028
Ss 15	2006	1970	2020	1928	1909	2040
Ss 16	1930	1931	1917	1953	1880	1954
Ss 17	1988	1943	1999	1945	1898	1947
Ss 18	1954	1971	1958	1961	1890	1941
Ss 19	1958	1978	1953	1960	1901	1962

SUBJECT RAW DATA
POINT TO POINT MEASURES: P300 AMPLITUDE

	Kit. 2: Fz Fr.	Kit. 2: P4 Fr.	Kit. 2: F3 Fr.	Kit. 2: Cz Fr.	Kit. 2: P3 Fr.	Kit. 2: F4 Inf.
Ss 1	1950	1959	1958	1922	1910	2081
Ss 2	2011	2011	2010	1891	1937	2103
Ss 3	1946	1919	1922	1918	1878	1968
Ss 4	1961	1926	1953	1911	1878	1998
Ss 5	1923	1934	1912	1924	1906	1960
Ss 6	1915	1902	1920	1891	1865	1946
Ss 7	1934	1886	1932	1898	1857	1950
Ss 8	1917	1884	1936	1892	1852	1976
Ss 9	1943	1922	1961	1924	1878	1971
Ss 10	1951	1927	1959	1885	1867	1969
Ss 11	1970	1957	1971	1929	1924	2080
Ss 12	2072	1924	2090	1937	1910	2132
Ss 13	1950	1944	1965	1881	1916	1988
Ss 14	2031	2011	2010	1933	1954	2014
Ss 15	2024	1996	2033	1920	1929	2053
Ss 16	1917	1913	1931	1930	1954	1965
Ss 17	1922	1940	1956	1925	1898	1979
Ss 18	1958	1980	1990	1954	1930	2114
Ss 19	1936	1935	1950	1924	1894	2019

SUBJECT RAW DATA
POINT TO POINT MEASURES: P300 AMPLITUDE

	Kit. 2: Fz Inf.	Kit. 2: P4 Inf.	Kit. 2: F3 Inf.	Kit. 2: Cz Inf.	Kit. 2: P3 Inf.
Ss 1	2066	1941	2100	1929	1895
Ss 2	2082	2073	2068	2002	1985
Ss 3	2000	1946	1963	1988	1912
Ss 4	1963	1921	1951	1915	1876
Ss 5	1980	1958	1984	1990	1947
Ss 6	1933	1959	1920	1923	1907
Ss 7	1949	1962	1932	1928	1911
Ss 8	1980	1979	1973	1954	1909
Ss 9	1960	1925	1957	1951	1888
Ss 10	1972	1956	1962	1958	1926
Ss 11	2050	1983	2078	1971	1942
Ss 12	2117	2021	2155	2022	1975
Ss 13	1981	1960	1977	1938	1916
Ss 14	2026	1943	1987	1957	1899
Ss 15	2047	2119	2030	2005	2068
Ss 16	1934	1948	1934	1950	1907
Ss 17	1971	1951	1982	1948	1924
Ss 18	1972	2061	1951	1979	1938
Ss 19	1980	2003	1962	1962	1955

APPENDIX B

RAW DATA FOR INDIVIDUAL SUBJECTS:

P300 LATENCY

SUBJECT RAW DATA
PEAK TO PEAK MEASURES: P300 LATENCY

	Tones:F4 Fr.	Tones: Fz Fr.	Tones: P4 Fr.	Tones: F3 Fr.	Tones: Cz Fr.	Tones: P3 Fr.
Ss 1	360	360	320	360	350	340
Ss 2	340	380	380	350	390	390
Ss 3	340	340	330	340	330	330
Ss 4	380	380	310	360	300	290
Ss 5	300	310	320	320	300	310
Ss 6	330	340	340	350	350	350
Ss 7	280	280	300	290	280	310
Ss 8	350	360	330	350	330	330
Ss 9	360	370	410	360	400	410
Ss 10	310	330	320	310	320	320
Ss 11	310	310	390	320	390	390
Ss 12	360	370	380	370	340	300
Ss 13	330	320	330	320	320	330
Ss 14	370	370	350	370	320	330
Ss 15	340	340	330	330	330	330
Ss 16	340	320	300	340	310	310
Ss 17	340	340	470	340	460	470
Ss 18	290	290	300	300	300	300
Ss 19	370	370	340	360	350	330

SUBJECT RAW DATA
PEAK TO PEAK MEASURES: P300 LATENCY

	Tones: F4 Inf.	Tones: Fz Inf.	Tones: P4 Inf.	Tones: F3 Inf.	Tones: Cz Inf.	Tones: P3 Inf.
Ss 1	360	360	350	360	350	350
Ss 2	350	350	330	340	380	380
Ss 3	360	370	340	380	370	340
Ss 4	360	360	350	370	350	360
Ss 5	350	370	330	360	370	340
Ss 6	340	340	330	340	340	380
Ss 7	310	300	320	310	310	320
Ss 8	320	330	320	340	320	340
Ss 9	330	360	380	330	380	390
Ss 10	290	290	330	300	320	320
Ss 11	360	360	380	350	380	370
Ss 12	390	390	380	380	380	390
Ss 13	350	310	330	310	310	310
Ss 14	320	320	320	320	310	320
Ss 15	340	340	320	340	320	320
Ss 16	360	350	360	350	340	370
Ss 17	330	340	330	340	330	330
Ss 18	300	300	300	310	300	310
Ss 19	340	350	310	340	350	340

SUBJECT RAW DATA
PEAK TO PEAK MEASURES: P300 LATENCY

	Kit. 1: F4 Fr.	Kit. 1: Fz Fr.	Kit. 1: P4 Fr.	Kit. 1: F3 Fr.	Kit. 1: Cz Fr.	Kit. 1: P3 Fr.	Kit. 1: F4 Inf.
Ss 1	840	840	840	840	830	820	600
Ss 2	910	910	950	880	910	950	700
Ss 3	830	820	1020	820	820	1000	670
Ss 4	760	740	740	740	750	750	750
Ss 5	740	730	800	740	740	800	920
Ss 6	830	830	840	850	800	790	1140
Ss 7	660	650	780	640	730	760	750
Ss 8	820	820	760	820	790	770	870
Ss 9	860	870	1000	870	870	1000	1010
Ss 10	640	650	610	650	700	590	810
Ss 11	610	620	620	620	610	630	820
Ss 12	850	840	920	840	840	820	880
Ss 13	980	980	1020	980	980	890	600
Ss 14	980	920	1010	980	980	1010	1010
Ss 15	1220	1200	1140	1210	1210	1140	980
Ss 16	790	790	680	800	660	630	750
Ss 17	1000	990	1000	970	970	990	820
Ss 18	760	810	880	750	720	940	710
Ss 19	740	740	820	800	710	930	670

SUBJECT RAW DATA
PEAK TO PEAK MEASURES: P300 LATENCY

	Kit. 1: Fz Inf.	Kit. 1: P4 Inf.	Kit. 1: F3 Inf.	Kit. 1: Cz Inf.	Kit. 1: P3 Inf.	Kit. 2: F4 Fr.
Ss 1	600	600	600	600	600	750
Ss 2	700	830	700	700	830	980
Ss 3	670	770	670	670	770	930
Ss 4	720	750	700	710	710	720
Ss 5	870	850	880	870	850	750
Ss 6	1130	1090	1130	1120	1080	810
Ss 7	730	660	730	730	700	960
Ss 8	870	840	870	940	840	880
Ss 9	1020	930	1030	1030	940	1010
Ss 10	800	800	800	790	790	830
Ss 11	830	890	800	910	900	690
Ss 12	880	590	890	880	570	920
Ss 13	600	600	600	600	610	900
Ss 14	1020	1090	1020	1020	1090	860
Ss 15	980	1010	960	1210	1010	840
Ss 16	750	700	750	740	700	810
Ss 17	820	1020	820	810	1010	900
Ss 18	710	960	710	710	960	820
Ss 19	670	1000	620	670	1000	800

SUBJECT RAW DATA
PEAK TO PEAK MEASURES: P300 LATENCY

	Kit. 2: Fz Fr.	Kit. 2: P4 Fr.	Kit. 2: F3 Fr.	Kit. 2: Cz Fr.	Kit. 2: P3 Fr.	Kit. 2: F4 Inf.
Ss 1	740	750	750	740	750	970
Ss 2	970	760	970	980	740	910
Ss 3	930	790	890	930	790	800
Ss 4	720	600	720	710	600	1060
Ss 5	740	720	750	730	720	960
Ss 6	820	820	830	820	770	720
Ss 7	970	740	820	810	770	740
Ss 8	880	880	890	870	890	740
Ss 9	1010	740	1010	730	740	1040
Ss 10	830	620	830	810	620	810
Ss 11	690	690	690	690	690	1000
Ss 12	920	920	920	920	920	830
Ss 13	900	580	900	610	580	720
Ss 14	890	420	880	850	410	850
Ss 15	840	700	820	840	690	810
Ss 16	770	740	770	760	770	790
Ss 17	870	890	870	870	870	1270
Ss 18	820	850	810	820	830	840
Ss 19	800	630	840	840	1000	920

SUBJECT RAW DATA
PEAK TO PEAK MEASURES: P300 LATENCY

	Kit. 2: Fz Inf.	Kit. 2: P4 Inf.	Kit. 2: F3 Inf.	Kit. 2: Cz Inf.	Kit. 2: P3 Inf.
Ss 1	970	960	970	960	950
Ss 2	910	910	890	900	910
Ss 3	790	860	790	780	870
Ss 4	1070	820	1070	1070	820
Ss 5	950	940	980	820	920
Ss 6	690	690	690	700	690
Ss 7	740	580	740	760	580
Ss 8	730	730	730	720	720
Ss 9	1100	960	1060	880	880
Ss 10	790	790	800	790	790
Ss 11	1000	850	1010	820	850
Ss 12	990	840	990	840	840
Ss 13	730	730	860	730	720
Ss 14	820	850	820	820	780
Ss 15	810	660	810	660	670
Ss 16	800	660	810	810	660
Ss 17	1270	1270	1270	1270	1270
Ss 18	830	870	800	710	840
Ss 19	920	730	990	990	710

VITA

Deanne Morgan Wilson was born in Hialeah, Florida on May 31, 1967. She attended Greater Miami Academy and received her GED from the State of Florida in 1983.

After numerous interruptions in her studies during which time she was employed in business and the dental profession she graduated from The University of Tennessee, Chattanooga with a Bachelor of Science degree in the dual majors of English and Education.

In the fall of 1994, she enrolled in the master's program in Speech Pathology at The University of Tennessee, Knoxville. In May, 1997 she graduated with her Master of Arts in Speech Pathology and accepted a position to serve as a clinical fellow speech-language pathologist with Lafayette Healthcare in Lafayette, Georgia.