CONCEALED INFORMATION AND FACE RECOGNITION USING BEHAVIORAL AND SPECTRAL ANALYSES

By

ADAM LEE LAWSON

Bachelor of Arts
Columbia College
Columbia, Missouri
1996

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1999

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 2001

CONCEALED INFORMATION AND FACE
RECOGNITION USING BEHAVIORAL
AND SPECTRAL ANALYSES

Thesis Approved:

Charles Abramson
Thesis Advisor

Bill Scott

B

Timothy J. Pettibone
Dean of the Graduate College

ACKNOWLEDGEMENTS

I wish to thank my committee, Dr. Charles Abramson, Dr. Douglas Hershey, Dr. Bill Scott, Dr. Bruce Ackerson, and Dr. William Warde for their time and assistance in this undertaking. My chairman, Dr. Charles Abramson deserves special recognition for his patience, help, and latitude he has given me in the years we have worked together.

I owe a large debt of gratitude to Dr. Marc Pratarelli for his constructive guidance, inspiration, dedication, and friendship, who without, I might not have achieved this honor. I wish to also thank Blaine Browne and Joy Jacobs-Lawson for their assistance in data collection and for finding time to edit one last draft.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Chapter 1: Introduction

The search for an accurate and reliable way to detect deception has occupied the attention of many researchers and criminologists since the beginning of modern civilization. In the past several decades, the polygraph has been used as a tool for detecting deceit. However, research has shown that the polygraph has low validity and reliability (Bashore & Rapp, 1993; Kleinmuntz & Szucko, 1982). Recently, several psychometric electrophysiological devices that measure central nervous system activity, e.g., electroencephalograms (EEGs), have been studied in the hopes of locating a specific cognitive process that indexes deception (Bashore & Rapp, 1993; Lawson & Pratarelli, 2000; Rosenfeld, Nasman, Whalen, Cantwell, & Mazzeri, 1987). Although an accurate and reliable way to use EEG to distinguish deception from nondeception has not yet been found, future prospects of using it seem promising. Specifically, Lawson and Pratarelli (2000) found several spectral EEG components that index concealed information. The goal and thesis of this dissertation is to continue exploring possible electrophysiological indices of deception using behavioral and EEG responses from truthful and deceptive participants who are presented faces related and not related to the scenarios they enact.

Historical Overview of Detecting Deception

Our world is filled with signs of deception, from the structural characteristics of a praying mantis being mistaken for a stick to the behavioral observations of primates placing food out of view when another approaches (Whiten & Byrne, 1988). According to Trovillo (1939), the purpose of deception is to mislead. Because the recipients of deception do not like being misled, society has advocated the use of methods and tools aimed at detecting and punishing those who lie.

One of the earliest known writings on detecting deception comes from the Ayur-Veda, a text concerning Hindu medical practices written about 900 B.C. (Trovillo, 1939). In the Ayur-Veda, there are specific guidelines on how to detect poisoners by their evasiveness of responses to questioning, face discoloration, and physical displays of anxiety such as rubbing a toe on the ground and rubbing the roots of one's hair. Another account of lie detection dated around 900 BC is the biblical tale of King Solomon and his technique for determining who was the rightful mother of an infant. Two women went before King Solomon both claiming to be the mother of an infant. When King Solomon threatened to cut the infant in half and give half to each claimant, one woman became emotional and stated that she would rather give her half of the infant to the other women than see the infant die. The other woman was more calm and acceptable of only getting half of the infant. King Solomon decided in favor of the woman who became emotional. Between 300 and 250 B.C., the Greek physician Erasistratus attempted to detect deceit by observing changes in a man's pulse who tried to conceal his intimate feelings for his stepmother (Lough & Kiesow, 1896). Thus, ancient methods of detecting deception associated both increases and decreases in emotion with deceit.

These early accounts of detecting deception are often based on logical thought and observation. However, many methods of lie detection collectively known as ordeals, relied on divine intervention, volition, and chance in determining innocence from guilt (Lea, 1866/1973).

Ordeal Method of Detecting Deception

Ordeals are methods of detecting deceit based on superstition and religious beliefs that the innocent are protected by a higher power while the guilty are not. Thus, the ordeal method of detecting deception does not involve any specific examination of the suspect, but requires the suspect to be subjected to some form of torture or perform some feat, test, or duel assumed to require mystical powers granted from a deity in order to complete successfully. Although anecdotal accounts of ordeals have been traced back to 1000 B.C., they were most pervasive from the first century AD to the end of the middle ages (Lea, 1866/1973).

Many ordeals used to prove one's innocence involved being subjected to some form of torture, like intense heat, without being harmed. The red-hot iron ordeal required the suspect to lick or grasp a red-hot iron. The boiling water ordeal involved either dipping the arm, or grasping an object in a pot of boiling water. Perhaps the simplest of ordeals involving heat, the fire ordeal, required the suspect to walk on or into a fire. For each of these ordeals, a suspect who completed the act unharmed was considered innocent, but if harmed, a guilty verdict was rendered.

A second type of ordeal required completing some feat or test. The ordeal of cold water required the accused to be lowered into a body of water with a rope. If the suspect did not become completely submerged, it was determined that the water's qualities of purity had rejected the suspect, and thus, indicated guilt (Lea, 1866/1973). The ordeal of the balance assumed that innocent suspects would become lighter in weight upon hearing a special prayer. The suspect was placed on a scale with an equal counterbalance and a water filled groove in the scale beam detected the slightest change in weight. It should be noted that a human will lose approximately 12 grams of weight per hour. Thus, a lengthy prayer would benefit the accused beyond its potential spiritual effects. One feat or test which, perhaps, was a precursor to modern lie detection measures involved chewing up rice powder and then spitting it out (Kleinmuntz & Szucko, 1984). If the discarded powder was dry, the suspect was presumed guilty. Historically, the volume of saliva has been known to diminish under situations of high stress and emotionality. Although diminished saliva was believed to result from the act of a higher power, these changes can be attributed to changes in the autonomic nervous system (ANS) (i.e., flow of saliva).

A third ordeal involved a duel or match between the accuser and accused. These ordeals assumed that innocent individuals would be given divine power to defeat the guilty. The ordeal of the cross was an endurance test between the accuser and the accused (Lea, 1866/1973). Both individuals would stand before a cross with their arms perpendicular to their chests and victory would be given to the individual who could remain in that position the longest. Thus, the individual who outlasted was considered truthful while the other was not. Other ordeals involved trial by combat where the accused and accuser, or champions of the two parties, fought until one was judged the victor or only one lived (Lea, 1866/1973). If the accuser lost, he/she was considered the loser; but if the suspect lost, then he/she was punished for the crime.

Towards a Scientific Approach to Detecting Deception

Although the previous discussion indicates the long historical interest and need for developing an accurate means of detecting deception, scientific investigations of deceit awaited the development of suitable apparatus capable of objectively measuring changes in emotion. Between the 16th and 18th centuries, several objective instruments for measuring emotions were invented, including an apparatus to measure the human pulse by Galileo in 1581, and an apparatus to measure blood pressure by Hales around 1733 (Clendening, 1931). In 1875, the Italian physiologist, Mosso, made great gains in the study of emotions. Mosso examined the effects of fear and sleep on pulse, blood pressure, and respiratory changes (Lee, 1953). During his studies, he developed several devices including the ergograph, which records muscular contraction, and the plethysmograph, which externally records changes in pulse rate and blood pressure via volume changes in organs or body tissue. Kiesow, a colleague of Mosso, also made several advancements in the measurement of emotions and is credited with stating that differences in blood pressure are the effects of emotions and accompanying sensations. Kiesow also argued that emotionality differs with different individuals, a statement that was later verified with studies of epileptics, psychotics, and neurotics (Lee, 1953).

Although Mosso and Kiesow made great advancements in the study of emotions, it is Lombroso, also a colleague of Mosso, who is credited with being the first scientist to apply scientific knowledge to detecting deception (Lee, 1953; Trovillo, 1939). Lombroso (as cited in Trovillo, 1939) described several experiments in which a plethysmograph was used during criminal interrogations. One incidence in which Lombroso used the plethysmograph to determine innocence or guilt occurred with a man suspected of murdering a young girl in 1902. Lombroso examined changes in the suspect's pulse rate when he performed simple arithmetic, looked at portraits of children who were covered with wounds, and when looking at the victim's photograph. Upon determining that the suspect's pulse rate had no sudden variations during the examination, Lombroso was able to determine that the man was innocent of the crime. Thus, Lombroso inferred that deception would result in increased pulse rate.

Detecting Deception Using the Word Association-Reaction Time Test

Since the time of Aristotle, scholars have known that memories are linked through associations (e.g., face with a name, smell with a certain food), and these associations can be used as a window to examine a person's thoughts (Munsterberg, 1908). In 1879, Galton began experiments that examined the association of ideas as a means to measure individuals' personality characteristics. From these experiments, he developed the word association-reaction time test. This test involved stating words one at a time to a participant who would respond to each word by stating the first word that came into his/her mind.

In the 1890s, Jung (as cited in Trovillo, 1939) further developed the word association-reaction time test to serve as a technique for detecting deception. He proposed the use of this test based on observations that court witnesses who lied seemed to hesitate before answering questions while truthful witnesses answered promptly. To scientifically test these observations, Jung performed several experiments examining reaction times to emotional and nonemotional words using the word-association task. Upon discovering that individuals responded slower to words that evoked an emotional response, Jung determined that differences between a suspect's reaction times to words related and not related to the criminal act could determine guilt from innocence. Due to several criticisms however, this lie-detection technique never became popular in field situations. For instance, Marston (1938) argued that Jung's reaction-time test was unreliable because it measured fear. Thus, the test was prone to error by the suspect's knowledge of the crime because any suspect, according to Marston, would show more fear upon hearing words related to the crime in contrast to non-crime words.

Furthermore, Marston found that a quarter of all individuals responded to words faster when deceiving.

Blood Pressure as an Index of Deception

Munsterberg is perhaps most recognized for his development of applied psychology in America. Among his accomplishments in the application of psychological principles, he advocated the use of blood pressure measures in determining the veracity of suspects in criminal investigations (Munsterberg, 1908). Munsterberg, curious about whether the Jung reaction-time test accurately distinguished deceptive from nondeceptive responses, had one of his students, Marston, determine its accuracy (Marston, 1938). Although Marston's research indicated that Jung's test was not highly accurate in indexing deceit, he observed that when participants lied, they seemed to put more effort and self-assertion into their responses. This insight led him to examine fluctuations in blood pressure as a possible indicator of guilt or innocence. With the approval from Munsterberg and acquisition of a plethysmograph, Marston performed a series of experiments that assessed the ability of blood pressure to index deception.

In one study, Munsterberg and Marston set-up a series of criminal acts that graduate students had or had not been guilty of committing (Marston, 1938). They assembled juries consisting of undergraduate students, had them witness mock trials of the graduate student suspects, and then render verdicts as to whether the suspects were guilty or not guilty of the crime. While each suspect was cross examined, blood pressure was recorded. Based on blood pressure changes in relation to suspects' responses, Marston, who was blind to the true guilt or innocence of the suspect, also made a determination of guilt or innocent. Of the 107 cases judged by both an undergraduate jury and changes in blood pressure, Marston reported that the mock juries made an incorrect verdict in over 50 percent of the cases whereas verdicts determined by changes in blood pressure were incorrect in less than four percent of the cases.

Marston's scientific examinations of detecting deception by observing fluctuations in blood pressure quickly gained public appeal and led to the development of the polygraph (Lykken, 1998). Thus, Marston is considered the grandfather of the polygraph. Larson, a medical student and employee of the Berkley Police Department, was intrigued by Marston's findings and subsequently developed the first interrogation polygraph in 1921. In addition to measuring blood pressure, this instrument also made continuous recordings of pulse rate and respiration (Kleinmuntz & Szucko, 1984). Although the use of his integrative polygraph quickly led to many successes, Larson (1932) remained skeptical of Marston's claims that the blood pressure test measured a specific lie response. Larson's (1932) skepticism towards Marston is noted by his reports that deception is not always accurately indexed by an increase of blood pressure. He went on to state that because of errors in lie detection tests, they should only be used in conjunction with other types of evidence.

Galvanic Skin Response as an Index of Deception

Although the Italian physiologist, Galvani, is credited with developing the first instrument (i.e., galvanometer) to index changes in the electrical conductance of the skin in 1791, its potential use to forensics was not reported until 1897 by Sticker (Trovillo, 1939). Sticker argued that changes in galvanic skin response (GSR) were attributable to changes in emotional states. Veraguth expanded on Sticker's work by examining the emotional sensitivity of the galvanometer using the association-reaction time test in 1907.

These initial observations of changes in GSR to emotional states were followed by several studies specific to indexing deception including the work of Summers (1936), Bril (as cited in Trovillo, 1939), and Marston (1938). These studies resulted in limited success. Summers (1936) reported an accuracy rate of 98 to 100 percent using GSR to distinguish deceit from innocence. Marston (1938) however, as part of the National Research Council to report on the applicability of lie detection, stated that GSR was not a practical metric of deception because of its over-sensitivity to any emotional or arousing event. Thus, GSR was considered largely uninterpretable in detecting deception.

Although the use of GSR in detecting deception was initially met with limited success, improvements in the galvanometer by Wilson and Keeler at Northwestern University resulted in a number of studies conducted at the Chicago Police Scientific Crime Detection Laboratory (Trovillo, 1939). These studies resulted in the development of specific criteria for distinguishing GSR of deceptive and nondeceptive responses (Inbau, 1942). Although these studies did not result in immediate use of GSR in field situations, refinement of techniques in measuring GSR has led to its favorable use as a critical index of deception.

Rise and Fall of the Polygraph

Keeler, an associate of Larson at the Berkeley Police Department, developed a portable field polygraph, known as the Keeler polygraph, and joined the Scientific Crime Detection Laboratory at Northwestern University (Inbau, 1942; Trovillo, 1939). At this laboratory, Keeler met John Reid, who developed his own polygraph, known as the Reid Polygraph. Later, Keeler and Reid established competing schools of polygraphy technique, and all polygraph examiners can trace their heritage back to one of these two schools.

Since 1922, polygraph devices have been used with great success in routine police work (Lee, 1953). In the early 1960s, polygraphers started expanding from police forensic laboratories to private industry (Lykken, 1998). By the 1970s, the use of the polygraph in the private sector had grown to the point that two million Americans took the test annually. During this period, numerous schools were established that taught polygraph techniques in six to eight weeks. Also, several scientifically trained supporters of the polygraph propelled it into a seemingly respectable, scientific tool for detecting deception.

Although the use of polygraph techniques reached its zenith in the 70s, building skepticism had emerged as researchers discovered that previous studies examining the accuracy of polygraph tests were greatly exaggerated (Lykken, 1979). This growing skepticism led to the federal Polygraph Protection Act in 1988, which prohibits most employers in the private sector from requiring or suggesting that prospective employees submit to polygraph testing. This act led to the downfall of the use of the polygraph by private industry. However, polygraph tests are currently still used by many law enforcement agencies in criminal investigations and by federal government agencies during preemployment and routine honesty screenings.

Traditional Approaches to Lie Detection

Traditional approaches to the psychophysiological detection of deception (PDD) all revolve around the use of the polygraph. The polygraph is a PDD tool that implicitly examines differences between physiological reactions to deceptive and nondeceptive responses by the participant to probing questions regarding the issue being addressed. The physiological reactions occur when the sympathetic autonomic nervous system (SANS) is aroused and when adrenergic neurotransmitters are released into the blood stream (Ford, 1995). SANS and adrenergic neurotransmitter activity are found by recording physiological responses such as cardiovascular, electrodermal, respiratory, and pupillary measures (Bradley & Janisse, 1981; Elaad, Ginton, & Jungman, 1992). In addition, several variations of polygraph examinations have been developed. These include the Relevant Question (Relevant-Irrelevant) Test (Marston, 1917), Comparison Question Test (Reid, 1947), Guilty Knowledge Test (Lykken, 1959), and the Directed Lie Control Test (Honts & Raskin, 1988).

The polygraph examination assumes that autonomic processes respond differently during deception versus nondeception. PDD measures have been found to discriminate between deception and nondeception at a rate higher than chance, but no reliable physiological response has been found that is directly related to deception (Elaad, 1994; Bradley & Janisse, 1981). Moreover, SANS activity and adrenergic neurotransmitters respond differently to many cognitive and emotional processes including anxiety, sensitization, fear, and anger (Ford, 1995; Kleinmuntz & Szucko, 1982). Thus, the assumption that conventional PDD approaches actually measure deception gives the polygraph questionable validity (Kleinmuntz & Szucko, 1982).

The Relevant Question (relevant-irrelevant) Test (RQT) developed by Marston (1917) is the oldest type of technique used in polygraph examinations (Ford, 1995). The RQT involves obtaining a baseline by asking several neutral questions. Once a baseline is obtained, a question relevant to the purpose of the examination is asked. For instance, a polygraph examination might ask irrelevant questions such as "Are you presently 25 years old?" and record different physiological responses in order to generate a baseline concerning the level of physiological reaction to truthful responses. Then, the polygraph examiner might ask several questions relevant to a criminal act such as "Have you ever stolen any equipment from your employer?" The polygraph examiner detects deception by comparing the baseline physiological reactions from irrelevant questions with physiological reactions to relevant questions. If the baseline reactions and relevant physiological reactions are determined by the examiner to differ significantly, then the participant is believed to be lying. The use of the RQT declined because a more valid PDD tool, known as the Comparison Question Test, was introduced.

The Comparison Question Test (CQT) developed by Reid (1947) and originally termed the Control Question Test, is currently the most common technique used in polygraph examinations (Ford, 1995). The CQT is similar to the RQT and involves asking examinees several comparison questions in which they are likely to lie. For example, the question "Have you ever lied to another person?" might be assumed to force the participant to lie. Then, irrelevant questions that are not intended to elicit a deceptive response are asked. Finally, questions relevant to the purpose of the examination are asked. Physiological responses between comparison and irrelevant questions are examined and differences in response levels are assumed to be caused by deceptive versus nondeceptive states. Examinees who have physiological reactivity to relevant questions versus irrelevant questions at a similar level to comparison versus irrelevant questions are determined to be lying.

One problem with the CQT is the assumption that certain questions will always elicit a deceptive response. This assumption holds that during an interrogation, the participant is fearful of admitting to any criminal or immoral act and therefore will lie to the investigator, even though virtually every person has committed the act (Ford, 1995). Theoretically, innocent participants should be more reactive to comparison questions than guilty participants. This potentially faulty assumption, along with the assumption that autonomic reactions detect deception is probably why the CQT has a false-positive error rate between 36 and 39 percent (Honts, 1994; Kleinmuntz & Szucko, 1982). Obtaining a baseline on the assumption that everyone lies to certain questions is the basis for calling the CQT a subjective test (Ford, 1995).

An alternative to the CQT, known as the Guilty Knowledge Test (GKT), was introduced by Lykken (1959). The GKT involves asking a participant multiple choice questions based on factual knowledge gathered from the crime in question. One alternative to each question is relevant to the crime while the other alternatives are unrelated. A physiological indicator compares the autonomic reactions of the crime-relevant alternative to the autonomic reactions of other crime-nonrelevant alternatives in order to determine deception. The GKT does not assume that physiological reactions measure deception. The assumption in the GKT is that physiological measures detect guilt because autonomic arousal related to remembering the criminal act will occur in a guilty participant (Bashore & Rapp, 1993). The GKT appears to correctly identify deceptive versus nondeceptive participants about 88 percent of the time, with a false positive error rate between five and zero percent, and a false negative error rate of around 12 percent (Kleinmuntz & Szucko, 1982; Bashore & Rapp, 1993).

Although the GKT seems to be highly predictive of deceit, it is not applicable in about 90 percent of the cases in which the polygraph can be used (Kleinmuntz & Szucko, 1982). The GKT requires that the polygraph examiner have specific knowledge of the crime (Ford, 1995). Because the GKT requires specific information about an act for which an examinee might be guilty, it can not be used with general honesty and integrity checks which account for about 90 percent of the Federal government's applications. The GKT can only be used when an act has been performed from which evidence can be collected. Because the GKT could only detect deception in limited situations, it did not become widely used in the field of lie detection.

A second alternative to the CQT, known as the Directed Lie Control Test (DLC), was developed by Fuse (as cited in Raskin, 1989) and formalized by Honts and Raskin (1988). The DLC is similar to the CQT in that both tests are interpreted in the same way and that the polygraph examiner asks several comparison questions to elicit a deceptive response, irrelevant questions that elicit a nondeceptive response, and relevant questions related to the deceptive act in question. However, the DLC does not assume that control questions alone will elicit a deceptive response. Therefore, the examiner instructs (i.e. directs) an examinee to lie to the control questions while thinking about an instance when they committed such a deceptive act. For instance, an examinee might tell a participant to lie to the question, "did you ever lie during your teenage years?", and also think about a particular instance when a lie was committed as a teenager. Proponents of the DLC suggest that it will accurately detect deception because all participants tend to focus on the questions that determine guilt from innocence (Raskin, 1989). Truthful participants should have enhanced concern on the control questions while deceptive participants should focus on the relevant questions in which they lie.

Honts and Raskin (1988) conducted a field study using the DLC on 25 criminal suspects. Their results revealed that 76 percent of guilty-innocent decisions were correct, eight percent were incorrect, and 16 percent of the decisions were inconclusive. Also, the DLC was found to be more time efficient, far easier to administer, and could be applied to many testing situations. Presently, the DLC appears to be a more accurate PDD measure than the CQT, but further research needs to be conducted in order to establish its validity and reliability.

New Approaches to PDD

In response to the weak validity and reliability of PDD measures that have practical use, researchers have very recently begun examining EEGs in the hopes of finding a better tool for the detection of deception or concealed information (Rosenfeld et al., 1987; Farwell & Donchin, 1991). EEGs have two main advantages over conventional PDD measures. First, EEGs measure cognitive processing where it actually takes place, in the central nervous system (CNS). In the present dissertation, cognitive processing refers to all processes by which sensory input is transformed, reduced, elaborated, stored, recovered, and used (Neisser, 1967). Because deception is a cognitive process, potential confounds concerning a participant's emotional state or anxiety may not pollute the EEG data as severely as found with SANS activity indexed by the polygraph. Thus, conventional PDD measures are not able to control for emotions or anxiety. Secondly, EEG data does not rely heavily on subjective procedures or interpretations from the examiner concerning the detection of deceit. EEG data have been found to be a reliable measure of cognitive processing despite differing levels of examiner skill (Bashore & Rapp, 1993).

EEG signals are rapid fluctuations in voltage generated in the CNS, but recorded from the scalp. All concurrent processing in cortical as well as subcortical structures is integrated in the EEG. Therefore, the EEG is considered a combination of the spatial and temporal summations of all electrical current-generators active at any given point in time. According to Wood and Allison (1981), the consensus of opinion is that the electrical activity recorded at the scalp reflects (for the most part) the spatial and temporal summation of both inhibitory and excitatory post-synaptic potentials of neurons that are actively polarizing and depolarizing. These voltage oscillations recorded in the EEG (known as brainwaves) are typically examined either in the context of environmental stimuli (e.g. event-related potentials) or internal states (e.g., arousal, sleep cycles).

Event-related Brain Potentials

Event-related potentials (ERPs) are measures of minuscule voltage changes (i.e., millivolts) time-locked to specific environmental stimuli. In order to separate these voltage changes from EEG activity that is unrelated to the time-locked stimuli, several samples (epochs) of an EEG signal are averaged together. In many cases, up to 200 epochs might be averaged together to produce a single ERP. Thus, the averaging process acts to reduce the signal-to-noise ratio allowing the relevant signal to rise above the background activity. The process of averaging electrical signals as a function of time allows researchers to average out activity that is not correlated with the time-locked presentation of the stimulus (Pratarelli, 1991). Cognitive processes may be measured using ERPs by examining average changes in the signal polarity and the time (in milliseconds) over which the changes in electrical activity take place. The remaining, correlated electrical signals are referred to as the ERP. The ERP has been shown to represent several synchronized neuronal populations whose processing are related specifically to the time-locked presentation of the stimulus.

A common distinction between early-onset and later onset ERPs is to refer to them as either exogenous (reflecting early sensory processing) or endogenous (reflecting perceptual and cognitive processing). Endogenous potentials can be further subdivided into automatic-cognitive processing and conscious-controlled processing. Potentials related to conscious-controlled processing are manipulated by psychological and cognitive variables, while automatic-cognitive processing cannot be consciously manipulated by the participant. For instance, attention is a conscious-controlled process that the participant can direct. Alternatively, the early stages of stimulus recognition are processes that are performed without the participant's attention or awareness.

The polarity of the ERP is either positive or negative, and specific potentials change as a function of the specific cognitive processes recruited following the presentation of the stimulus. Most ERPs are labeled using the symbols "P" or "N" representing the positive or negative polarity of the wave, and a number or numbers representing the placement of the wave in relation to stimulus onset. For example, P300 and N4 represent specific ERPs. P300 represents a positive wave that peaks around 300 ms, and N4 represents the fourth negative wave following the onset of a stimulus. However, there are many occasions in which P300 and N4 can be represented as P3 and N400, respectively. The most efficacious convention to use is the actual time, in milliseconds, where the number represents the latency of the peak of the waveform in question. For instance, while N400 represents a class of ERPs, a particular N400 from any given study could be represented as N450 (Pratarelli, 1994).

P300

The P300 wave has been the most widely studied component of cognitive ERPs (Rugg & Coles, 1996). Traditionally, the most common method of studying the P300 is by utilizing the oddball paradigm. The oddball paradigm typically consists of presenting two classes of events where one class is rarer than the other, and participants respond in some way to the rarer class. For example, a participant is presented a list of words and is asked to count the number that are not categorized as vegetables. Several words depicting vegetables (e.g., celery, pumpkin) are presented in serial order followed by a word not related to vegetables (e.g., token). The occurance of the word not categorized as a vegetable is rare and thus, indexed as a P300. Studies utilizing the oddball paradigm have found that the amplitude of the P300 component is inversely related to the probability of occurrence of a stimulus (Johnson, 1986). However, the latency of the P300 component (300 to 900 milliseconds) seems to be related to the ease with which a stimulus can be categorized into one of the two classes, with more difficulty in categorization being reflected by longer latency (Donchin & Coles, 1988). Using the previous example, if the word 'apple' were to be displayed instead of 'token', it would be reflected by a longer latency P300 because it is more difficult to distinguish 'apple' from vegetables than 'token'.

N400

The N400 component of ERPs has been found in response to unexpected or inappropriate linguistic, semantic, or episodic contextual violations (Kutas & Hillyard, 1980; Pratarelli, 1994; Fischler, Childers, Achariyapaopan, & Perry; 1985). For example, "roses are red" is a common phrase with red being commonly associated with roses, but "roses are black" is a contextual violation because roses are not commonly associated with the color black. In lie detection, the N400 should be elicited when a participant with knowledge of a crime related event is given a false sentence related to that crime, i.e. a contextual violation relative to that crime. The N400 should not be elicited if a participant does not have knowledge of a crime related event (Boaz, Perry, Raney, Fischler, & Shuman, 1991).

Overview of PDD Research Utilizing ERPs

Previous ERP research in detecting deception has focused on the P300 and N400 windows (Allen, Iacono, & Danielson, 1992; Boaz et al., 1991; Farwell & Donchin, 1991; Rosenfeld, Angell, Johnson, & Qian, 1991; Rosenfeld et al., 1987; Stelmack, Houlihan, & Doucet, 1996). These studies have focused on detecting deception by examining a participant's behavioral response to familiar, unfamiliar, and probe stimuli.

Rosenfeld et al. (1987) examined differences in poststimulus ERPs between 400 and 700 ms related to a chosen item and eight novel items. A mock crime involving theft was constructed and participants were asked to take one item out of a box containing nine items. Following the mock theft, ERPs were recorded while participants were shown nine words on a screen, eight novel and one depicting the item they chose. Results revealed a significant difference ($p<.001$) between the ERP averages concerning chosen versus novel items. Specifically, positive peaks, either being distinct P300 waves or a broad positive area, were found in response to the chosen item. However, novel item responses did not show consistent positivity during the critical time period. Thus, ERPs reveal that cognitive processing of verbal stimuli is different for familiar versus relatively unfamiliar stimuli. Rosenfeld et al.'s (1987) finding supports previous studies concerning an oddball paradigm in which a familiar item evokes a P300 when contrasted with several non-familiar stimuli (Duncan-Johnson & Donchin, 1977).

Farwell and Donchin (1991) examined crime-related scenarios and participants with a criminal past history to explore whether the P300 could accurately detect deception. Participants participated in one of two crime-related scenarios with each group being guilty of committing one mock crime, but not the other. Stimuli consisted of phrases relevant to each scenario and specific phrases that participants rehearsed and were instructed to detect. Results of averaged ERPs across participants for each trial type demonstrated that the P300 was elicited by familiar phrases only. Thus, the P300 distinguished between familiar and unfamiliar stimuli. Also, using a bootstrapping procedure which allows for the approximation of an unknown sampling distribution, the P300 correctly distinguished between familiar and unfamiliar phrases for 83 percent of the trials.

Allen et al. (1992) examined the use of the P300 wave in distinguishing concealed from unconcealed information using a verbal learning task. Unlike Farwell and Donchin (1991) however, they utilized a Bayesian classification system to distinguish between deception and nondeception. The Bayesian technique is based on Bayes theorem which includes prior probabilities of an event taking place in distinguishing between groups. Also, implicit measures including reaction time and number of incorrect responses were collected. Participants blindly chose a category containing 6 words and studied the items until they could serially recite the items in both forward and reverse order. Following a delay period, participants were given a second similar, but unrelated, category list to memorize. Upon memorization of the second set of items, participants were given a computer task where they responded to words from the second category as familiar to them, but concealed their knowledge of the first set of words. The computer task comprised randomly presenting learned items and novel items. In order to elicit the P300 wave, an oddball paradigm was employed where 20 percent of the stimuli were familiar and 80 percent of the stimuli were novel. The method was cross-validated across three samples. Results indicated that Bayesian classification using ERPs correctly classified learned from unlearned material in 94 percent of the cases. Furthermore, the measures of implicit memory (reaction time, number of incorrect responses) could be used to correctly classify 95 percent of the learned items and 96 percent of the unlearned items.

Allen and Iacono (1997) analysed data reported in Allen et al. (1992) to examine differences between three classification systems; the cross-correlational bootstrapping technique used in Farwell and Donchin (1991), a simplified bootstrapping technique using peak amplitudes, and the Bayesian classification results in Allen et al. (1992). Also, Allen and Iacono (1997) evaluated the efficacy of these three techniques by examining the influence of motivational factors in asking participants to conceal information, lie, or lie successfully in order to receive a reward. The cross-correlational bootstrapping technique was used to examine the accuracy in distinguishing between concealed items, targets (items familiar to the participant but not concealed), and nontargets (items unfamiliar to the participant) while a bootstrapping technique which compared peak amplitudes was used to distinguish between concealed and target stimuli. Results revealed that concealed information was identified as familiar to the participant in 87 percent of cases using the cross-correlational bootstrapping technique, 80 percent of cases using the amplitude-based bootstrapping technique, and 92 percent of the cases using the Bayesian technique. Unlike the amplitude-based bootstrapping technique, however, the cross-correlational bootstrap procedure increased significantly in classification accuracy as participants were given increased incentives to deceive.

Thus far, the ERP studies discussed in detecting deception have utilized a design similar to the GKT in that specific knowledge about the deceptive act is required in order to determine guilt from innocence. However, Rosenfeld et al. (1991) examined the P300 utilizing a design similar to the CQT in that no specific information about the deceptive act is required to distinguish deceptive from nondeceptive responses. All participants completed a checklist containing 13 items relating to various antisocial acts. After completing the checklist, participants were accused of committing four of the 13 acts. Participants in the guilty condition had committed one of the four accused acts while participants in the innocent condition had not committed any of the four accused acts. Participants then took a lie detector test portrayed as a character and integrity screening used to gain entry into a hypothetical government position. Participants in the guilty group responded to seven phrases of which they were innocent, one phrase in which they were guilty, and one phrase that verified participants' attention to stimuli. Participants in the innocent group responded to eight phrases of which they were innocent and one phrase that verified participants' attention to stimuli.

Results from Rosenfeld et al. (1991) revealed no main effect for group. However, their was a stimulus by group effect for peak to peak amplitude data. This interaction indicated that guilty participants were indexed by higher P300 amplitudes for the guilty phrases. Also, no significant differences were found for either guilty or innocent participants concerning false accusations.

Boaz et al. (1991) examined the utility of the N400 in discriminating between participants who concealed information and participants who did not. As previously discussed, the N400 is expected to be elicited when a participant with knowledge of a crime related event is given a false sentence related to that crime (i.e., a contextual violation), while it should not be elicited if a participant does not have knowledge of a crime related event. Participants watched either a video of a crime (guilty condition) or scenes of New York City (innocent condition). Participants in the guilty condition were asked to conceal information related to the crime while innocent participants were told to respond truthfully but not to freely communicate any information directly to the examiner. Participants then read crime related phrases that ended in either true or false components. Analysis of N400 mean amplitudes across conditions and stimulus types revealed that guilty participants differed on truthful versus false stimuli ($p < .01$) while no differences were found for innocent participants relating to stimulus type. Also, analysis of individual participants revealed that 78 percent of the participants could be correctly classified as guilty or innocent.

Stelmack et al. (1996) examined differences in P3, N4, and N2 ERP components using a two-stimulus paradigm in which the first stimulus was a question followed by a second stimulus consisting of a yes/no response. This design is similar to studies that have utilized a match/mismatch paradigm because the yes and no targets occurred with equal probability (Pritchard, 1981). Participants were assigned to either a deceptive group, involving the enactment of a crime-related scenario, or an innocent group which did not contain any criminal acts. Following scenario enactment, participants in the deceptive condition were instructed to conceal knowledge related to the criminal scenario while participants in the innocent condition were instructed to remain truthful to scenario related items. Participants were then presented questions relevant and not relevant to the criminal act followed by a yes/no target in which they were asked to respond as to whether the question and target were congruent or not. Results revealed that the amplitude of the P3 waveform was smaller for deceptive participants responding to crime-related stimuli with an incongruent target. Participants in the innocent group had larger P3s for any stimulus type. However, differences in N4 and N2 components did not conclusively distinguish innocence from guilt.

Limitations to PDD Research Utilizing ERPs

Although the potential use of ERPs in the detection of deception remains optimistic, several problems remain in terms of using the described techniques in field situations. First, with the exception of Rosenfeld et al. (1991), ERP studies examining deception require specific information about a criminal act to index deceit from nondeceit, and are in effect, similar to the Guilty Knowledge Test (GKT) used in polygraph testing. As stated previously however, the GKT is not applicable in about 90 percent of the cases in which the polygraph is used. Rosenfeld et al. (1991) introduced a method similar to the Comparison Question Test (CQT) in that no specific information related to a crime was required to index deceit. However, this method utilized the oddball paradigm, which requires deceptive events to be rarer than nondeceptive events. Although a stimulus set containing a smaller set of relevant acts than irrelevant acts may provide an accurate metric of deception, there is no guarantee that examinees will respond innocently to irrelevant stimuli. Therefore, the potential for error is large.

Spectral Analysis

An accepted principle in neuroscience is that neurons which are activated relatively at the same time coalesce into cooperating groups. Hence the saying, 'neurons which fire together wire together.' Electrical activation of cooperating neurons can be indexed by rhythmic activity that comprises much of the resting EEG (Salansky, Fedotchev, & Bondar, 1995). Therefore, rhythmic activity measured at the scalp is a function of the collective oscillations generated by groups of neurons firing in synchronous patterns.

Spectral analysis is the process of taking an epoch from the EEG waveform and breaking it down into components related to the frequency domain (Wong, 1991). Decomposition of a time epoch into spectral components is usually performed using Fourier analysis, which defines a number series in terms of sine wave components, that, when added together, would give the original pattern. Fourier analysis is very laborious computationally, and thus, is typically approximated using Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT), or Inverse Fourier Transform (IFT) algorithmic procedures (Empson, 1986; Salansky et al., 1995). The procedures differ in that FFTs provide a wide range of options but are limited by the number of data points that can be analyzed, DFTs are useful when a narrower analysis is needed, and IFTs are useful when only a narrow band of the spectrum is of interest. Figure 1 represents a typical power spectrum plot after DFT analysis. The amount of activity at every frequency (between 1 and 32 Hz) is represented in terms of power. Power is the amount of amplitude

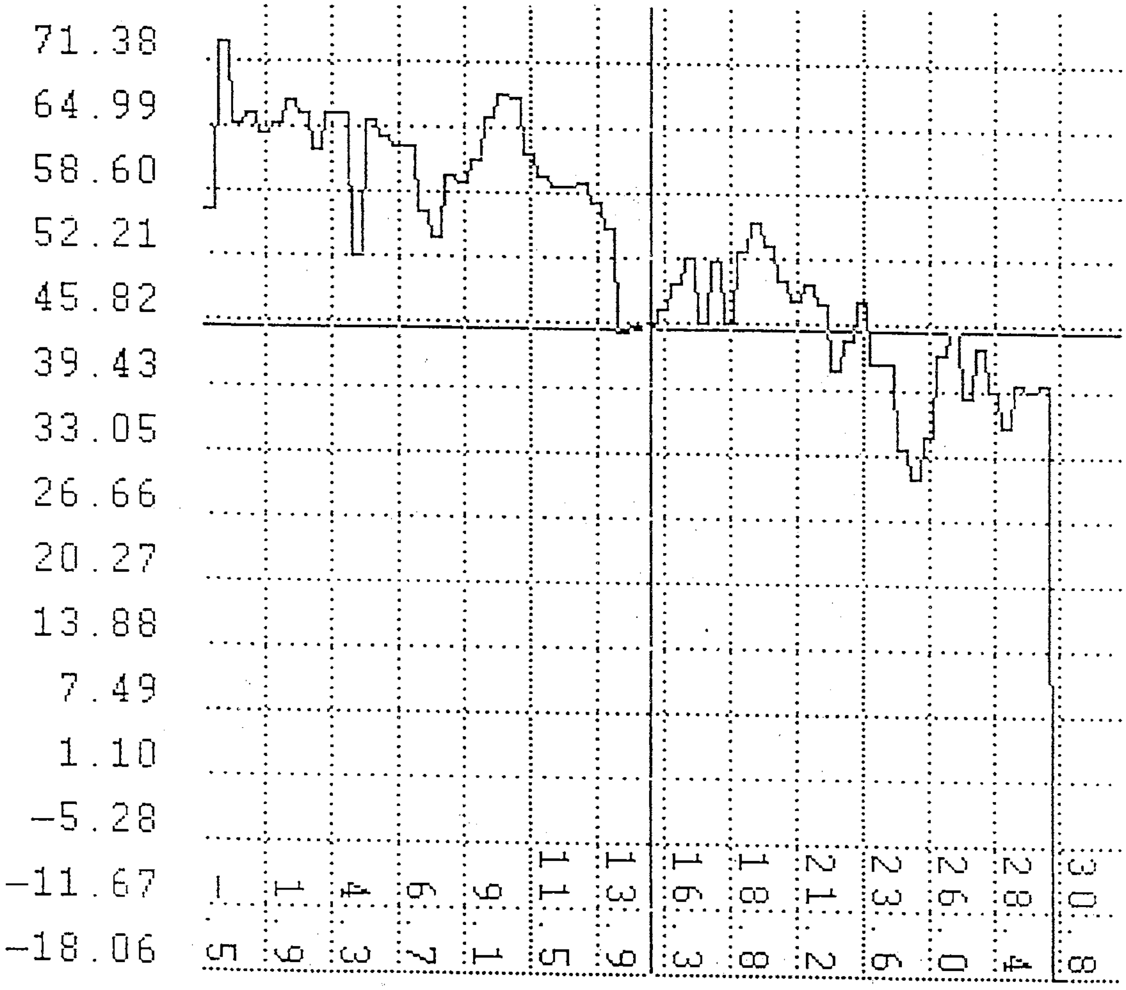


Figure 1. An example of a power spectrum plot. Power spectrum is examined using relative magnitude, in decibels along the Y axis, and frequency, in hertz along the X axis.

(expressed in decibels) at any given frequency or sampling point. Spectral analysis of EEG allows for objective quantification within particular frequency bands which have been correlated with different psychological states. Common frequency bands include delta (1 - 4 Hz), theta (4 – 7.5 Hz), alpha (7.5 – 12.5 Hz), beta (13 - 30 Hz), and gamma (30 – 70 Hz) (Andreassi, 1989; Basar, Basar-Eroglu, Karakas, & Schurmann, 2000; Klimesch, 1999).

Research indicates that the frequency range which distinguishes differing spectral bands, especially with respect to alpha and theta, shows large inter-subject variability (Doppelmayr, Klimesch, Pachinger, & Ripper, 1998; Klimesch, 1999). Distinguishing between individual differences of frequency bands is typically achieved by locating the <u>individual alpha frequency</u> (IAF) defined as the frequency between 7.5 and 12.5 Hz with the highest power (Klimesch, 1997).

Research on sleep, vigilance, and general arousal show that in general, slow frequencies (delta, theta, alpha) reflect low levels of mental activity while higher frequencies (beta, gamma) reflect more complex levels of mental activity (Davidson, Jackson, & Larson, 2000). As shown in Figure 1, lower frequencies typically have high levels of power, indicative of a large number of neurons synchronized in a regular fashion. In contrast, higher frequencies typically have lower levels of power and reflect smaller populations of neurons oscilating in irregular intervals. Therefore, synchronization is generally thought to reflect activation, and based on this premise, spectral bands are considered to reflect independent states of awareness and mental activity. The following is a general overview of frequency bands and mental processes associated to each.

1. Delta waves have long been used to index deep sleep, and have been found to increase during sleep with increased mental activity the previous day (Horne & Minard; 1985). More recently, changes in delta activity have been found in relation to tasks that elicit the P300 ERP (Basar-Eroglu, Basar, Demiralp, & Schurmann, 1992) and to increase in power to mental tasks requiring attention to internal processing (Harmony et al., 1996).
2. Studies of theta activity in nonprimate mammals have found that these oscillatory neurons originate in the hippocampal formation, and thus may reflect coding of long-term memories (Lopes da Silva, 1992). Research on humans has generally supported the notion that theta reflects memory processes in that it seems to synchronize (indexed by increased power) with increasing task demands, specifically with increases in encoding and recognition stages of memory (Klimesch, 1999; Lopes da Silva, 1992; Weiss & Rappelsberger, 2000).
3. Alpha waves are perhaps the dominant frequency in adult human EEG (Klimesch, 1999). They occur primarily during an awake state over the posterior regions of the head. Also, alpha is most evident when participants close their eyes and are relaxed (Adrian & Matthews, 1934; Empson, 1986). Generally, alpha desynchronizes (indexed by lower power) with increasing task demands (Klimesch, 1999; Krause et al., 2000). Thus, theta and alpha respond in opposite ways in that alpha desynchronizes and theta synchronizes with increased task demands. Researchers have found two distinct components of alpha activity, distinguished as lower and upper alpha (Basar et al., 2000; Williamson et al., 1996; Klimesch, 1996). Lower alpha (ranging about 6 – 10 Hz) is topographically widespread over the entire scalp and reflects different types of

attentional processes and general task demands (Gevins, Smith, McEvoy, & Yu, 1997; Klimesch, 1999; Klimesch, et al., 1996; Shaw, 1996; Weiss & Rappelsberger, 1996). Upper alpha (ranging about 10 - 12 Hz) is topographically restricted and is sensitive to semantic processing (Klimesch et al., 1996; Klimesch, Doppelmayr, Pachinger, & Ripper, 1997; Klimesch, Doppelmayr, Pachinger, & Russegger, 1997).

4. Beta activity has been long known to reflect a mentally active, alert state, and is characterized by irregular electrical activation substantially lower in power than alpha. Accordingly, differences in beta power have been found to distinguish participants based on higher mental functions including reading abilities (Ackerman, Dykman, Oglesby, & Newton, 1994), working memory performance (Tallon-Baudry, Kreiter, & Bertrand, 1999), and deception (Lawson & Pratarelli, 2000).
5. Gamma activity (also known as beta II) has recently been examined with increased interest, specifically with frequencies centered around 40 Hz (Kelso, 1999; Sheer, 1984). Studies have found gamma activation with both visual and auditory stimuli (Basar, Rosen, Basar-Eroglu, & Greitschus, 1987; Eckhorn et al., 1988), attentional process (Tiitinen et al., 1993), and reflecting an interaction between general cortical arousal and the processing of sensory information (Spydell, Ford, & Sheer, 1979; Loring & Sheer, 1984).

PDD Research Utilizing Spectral Components

Previous spectral component research in detecting deception has focused on the Beta bandwidth (Lawson & Pratarelli, 2000). Lawson and Pratarelli (2000) examined the similarities and differences that characterize the behavioral (reaction time and response accuracy) and power-spectra (high peak frequency, high peak amplitude, low peak frequency, and trough amplitude) responses in truthful and deceptive participants. In their initial experiment, half of the participants participated in a mock crime involving espionage while the other half participated in a non-crime scenario. The use of scenarios allowed participants to gain first-hand knowledge, and thus, was considered similar to participants' knowledge base in field situations. Participants in the deceptive condition were instructed to deny anything related to their scenario but answer truthfully to all other items while participants in the innocent condition were instructed to respond truthfully to all items. The participants responded during their session to words related to their respective scenario and not related (i.e., related to the alternative scenario, personally familiar items, and foils) to the scenarios they enacted.

Results of this initial experiment with respect to behavioral data revealed significant interactions of groups by stimulus category for both reaction time ($p < .001$) and response accuracy ($p < .001$) (Lawson & Pratarelli, 2000). Deceptive participants were both faster and more accurate in responding to espionage, errand, and foil word categories than innocent participants. Results also revealed significant differences between spectral potential averages concerning deceptive versus non-deceptive participants. Specifically, the frequency of the high peak amplitude was higher for deceptive participants at Fz (i.e. anteriorly) than innocent participants, while the high peak amplitude was higher for innocent participants at Pz (i.e. posteriorly) than for deceptive participants. Also, the frequency of the trough amplitude was higher for deceptive participants at F7/F8 (i.e., anteriorly) than innocent participants, while the trough amplitude was higher for innocent participants at T3/T4 (i.e., posteriorly) than deceptive participants.

The significant differences between anterior and posterior processing irrespective of stimulus type indicated that beta activity may index a general state of arousal representing cognitive processes underlying deception (Lawson & Pratarelli, 2000). Moreover, their findings may indicate the presence of a CNS marker that does not require specific information related to the deceptive act to index deception, because the spectral beta findings did not differentiate items a deceptive participant concealed from items the participant answered truthfully. However, the increased accuracy and responding speed of deceptive participants may have indicated that cognitive mechanisms not directly related to deception also accounted for differences found between groups. Specifically, the authors suggested that intrinsic motivation, defined as the motivation of a behavior that is dependent on factors internal in origin, and task demands may have accounted for differences found between deceptive and nondeceptive participants.

Based on their initial findings, Lawson and Pratarelli (2000) performed a quasi-replication study. This quasi-replication reflected several modifications for decomposing the EEG spectra from the initial experiment in that (a) word stimuli were presented in block format (as opposed to the random presentation of stimuli in the initial experiment) in which all stimuli in their particular category were presented together, (b) the EEG data were subjected to DFT transforms (as opposed to FFTs used in the initial experiment), and (c) amplitudes of each frequency point in the beta bandwidth were analyzed instead of the peak-to-peak method utilized in the initial experiment. Also, a questionnaire consisting of three questions that indexed intrinsic motivation was given to participants just prior to completion of the experiment.

For the quasi-replication study, only midline spectral beta data were reported. A group by frequency interaction (p < .028) indicated that beta activity from 23 to 26 Hz distinguished deceptive from innocent participants. In contrast to their initial experiment, however, group differences were not found with respect to anterior versus posterior processing. Analysis of the self-report measure that indexed intrinsic motivation did not reveal any significant effects.

One aim of the present dissertation is to expand on Lawson and Pratarelli (2000) by examining whether differences exist between anterior and posterior spectral components when using faces, which may be a more generalizable stimulus type than words. Moreover, the use of a lie-detection technique using faces may be useful in determining the validity of eye-witness testimony. Another aim of the present thesis is to examine the influences of intrinsic motivation and task demands on deceptive behavior.

Psychophysiological Aspects of Face Recognition

A large number of studies have examined face recognition in terms of localization of function and stages of processing that are specialized for this task. Overall, research has found that brain processes related to face recognition occur primarily in the temporal lobes, and their interaction with the occipital, hippocampal, and frontal areas (Rajah, McIntosh, & Grady, 1999; Rolls, 1992; Sergent & Signoret, 1992). In addition, the right hemisphere plays a more prominent role than the left hemisphere in certain aspects of face processing.

Ungerleider and Mishkin (1982) were the first to propose that the recognition of visual stimuli occurred in terms of a ventral stream of information starting in the occipital lobe and terminating in the temporal lobe. Research on face recognition has largely supported this theory in that face specific neurons have been localized mainly in the superior temporal sulcus and inferior temporal cortex of the temporal lobes. Specifically, studies using microelectrodes have found that neurons in the superior temporal sulcus process faces in terms of 'social attention' (Perrett, Hietanen, Oram, & Benson, 1992). Social attention refers to neurons that respond differentially in relation to the focus of an individual's attention and processing information primarily based on the direction of another's gaze and differing views of the head (frontal, side, & back profiles). The inferior temporal cortex seems to process information in terms of face identity with neurons being selectively activated in terms of the whole face, specific parts of the face, or with specific features of the face (Rolls, 1992). Also, the anterior temporal cortex has been found to reflect activation of biographical information related to faces, but does not seem be exclusively related to face processing (Sergent, Ohta, & MacDonald, 1992).

Two structures within the occipital lobes, the lingual and fusiform gyri, have been examined with increased interest in terms of face recognition. Sergent et al. (1992) performed PET scans on several prosopagnosia (a disorder characterized by the inability to recognize faces) and normal participants and found that activation of the left fusiform gyrus was only apparent with an object categorization task, thus implying that it was not involved in processes specific only to faces. However, the right lingual and fusiform gyri were found to process face specific information in terms of face arrangement and unique characteristics that define each face.

Similar findings revealing the importance of the right fusiform gyrus in face recognition were found by Watanabe, Kakigi, Koyama, and Kirino (1999). They examined ERPs and found that faces were distinguished from other visual stimuli by a positive wave occurring around 200 ms post-stimulus and by two negative components occurring 190 ms post-stimulus at electrode locations T5 and T6. Also, the negative peak at electrode T6 (located over the right hemisphere) was larger than the peak at electrode T5 (located over the left hemisphere). These ERP findings, along with the use of magnetoencephalography (a new type of recording system that has both high temporal and spatial resolution), were shown to reflect the right fusiform gyrus' dominance over the left fusiform gyrus in facial processing.

Haxby et al. (1996) examined PET scans of 10 normal adults while they performed face encoding, face recognition, face perception control, and sensorimotor control tasks. Increases in regional cerebral blood flow (rCBF) specific only to the face encoding task were found in the right medial temporal region which included the hippocampus, left prefrontal cortex, and the left inferior temporal gyrus. Increases in rCBF specific only to the face recognition task included the right prefrontal cortex, mid and inferior frontal gyri, bilateral ventral occipital cortex, and cerebellum. Also, bilateral activation of the inferotemporal and fusiform gyri were found during both face encoding and recognition tasks in comparison to the control tasks. They suggested that the lack of temporal lobe activation in the recognition task may have been due to the relatively short interval between encoding and retrieval. However, localization of processes related to these recent memories is not, to date, been empirically substantiated. Haxby et al. (1996) also suggested that the increased activity found during the encoding phase in the right hippocampal region reflected the processing of novel stimuli. This interpretation is consistent with findings from Gur et al. (1997) in that right parahippocampal activity was related to participants' ability to correctly reject foils during a face recognition task.

Rajah et al. (1999) re-examined Haxby et al.'s (1996) PET scan data using a structural equation modeling technique. Structural equation modeling allows the researcher to specify a theoretically or intuitively based graphic representation (i.e., model) of the relationships between multiple variables of interest. Rajah et al. (1999) found that all tasks involving the processing of faces involved a positive influence of the occipitotemporal area on the medial temporal cortex in the left hemisphere, and positive input from the middle temporal cortex to the lateral prefrontal cortex in both hemispheres. Bilateral feedback from the lateral prefrontal cortex to the occipitotemporal and middle temporal cortices was found only when participants were required to make a choice between two faces. Specific to face recognition, there was a neural loop in the right hemisphere from the occipital lobe to the frontal lobe and back from the frontal lobe to the occipitotemporal lobe. Also, the occipitotemporal area positively influenced the right hippocampal region. Although the specific function of the right parahippocampal area and right pre-frontal lobe are not fully understood in terms of face recognition, these studies suggest that these areas of the cortex are critical to understanding the processes involved.

An interesting note in light of the findings by Haxby et al. (1996) and Rajah et al. (1999) is that their results were similar to Tulving, Kapur, Craik, Moscovitch, and Houle (1994) with the lateralization of encoding and retrieval of words. Tulving et al. (1994) found that the ventrolateral frontal cortex of the left hemisphere is preferentially active during memory encoding of words, while the right frontal cortex and the bilateral posterior parietal cortex were found to be active during memory retrieval of words.

As suggested in the previous paragraphs, processes related to the recognition of faces are disproportionately greater in the right cerebral hemisphere. Perhaps the most substantial evidence of right hemispheric superiority came from studies which found that patients who had brain damage in the right hemisphere were more impaired in recognizing faces than patients with damage in the left hemisphere (Kolb, Milner, & Taylor, 1983; Silva, Leong, & Wine, 1993).

Moscovitch, Scullion, and Christie (1976), using a face matching task, found no hemispheric asymmetries when the inter-stimulus interval (ISI) was below 100 milliseconds. When the ISI exceeded 100 milliseconds, however, differences between hemispheres emerged. They suggested that the superiority of the right hemisphere in matching faces only occurred when the ISI was large enough to prevent the perceptual comparison of the two faces.

Schweinberger and Sommer (1991) used behavioral (reaction time) and ERP measures to examine whether the right hemisphere's advantage in processing faces was due to stimulus encoding or to memory search processes. A recognition task was used in which stimuli were presented in a lateralized fashion to examine differences in processing to faces presented in the left versus right visual field. To examine the influence of stimulus encoding, stimuli varied in respect to picture quality. Memory search processes were also examined by presenting several stimulus blocks differing in terms of the number of faces to be memorized (i.e., memory set size). Results revealed that for large memory set sizes, faces presented in the left visual field (processed in the right hemisphere) had faster reaction times than faces presented in the right visual field (processed in the left hemisphere). However, hemispheric asymmetries were not found with respect to the quality of faces. Also, ERP differences in latency of a positive wave occurring around 570 milliseconds post-stimulus onset corroborated the finding that hemispheric differences in face recognition can be attributed to memory set size. Thus, their findings suggest that the two hemispheres do not seem to differ in terms of encoding face stimuli, but the right hemisphere's superiority reflects the efficiency of memory processes.

To date, only two studies are known to have examined facial recognition in terms of spectral components. Burgess and Gruzelier (1997) examined the ability of spectral EEG components to localize cognitive functions related to the recognition of faces. Mean amplitudes were collected with respect to both acquisition and recognition of faces in delta, theta, alpha, beta 1 (13 – 16 Hz), and beta 2 (17 – 30 Hz) bands using FFTs. Topographic maps were then developed using the method of spherical splines.

Spherical splines is an interpolation technique used to generate distribution maps of a particular physical parameter at the surface of the scalp (Perrin, Pernier, Bertrand, & Echallier, 1989; Perrin, Pernier, Bertrand, Giard, & Echallier, 1987). Interpolation is the process of estimating, on the basis of information taken from two or more electrodes, information that lies between these electrodes (Gratton, 2000). Thus, interpolation allows researchers to derive representations of the activity over the whole scalp from electrodes placed within and along the scalp's parameter.

Burgess and Gruzelier (1997) used the spherical splines technique to localize scalp distributions of the mean amplitude data. Analyses of amplitudes of spatial distributions related to acquisition and recognition were also performed. Results indicated that the alpha, beta 1, and beta 2 bands differed between acquisition and recognition of faces in the right temporal and parietal regions. Also, a significant correlation was found with alpha activity in the temporal region and performance on the task.

The second study examining facial recognition using spectral components was also performed by Burgess and Gruzelier (2000). This study examined ERD of theta, lower alpha, and higher alpha bands in relation to word and face recognition tasks. For both word and face memory tasks, participants completed a computer task containing 90 trials. Each trial consisted of the presentation of one stimulus (i.e., word or face) and participants were asked to indicate whether each particular stimulus had been previously seen. The first 10 trials consisted of stimuli that were new to participants. For the latter 80 trials, five stimuli viewed by participants during the first 10 trials were each randomly repeated eight times, for a total of 40 trials. The other 40 trials consisted of stimuli that participants had not previously seen.

Results indicated differences with respect to repeated versus nonrepeated words for theta ERD data (Burgess and Gruzelier, 2000). However, this repetition effect was not indexed with theta ERD for face stimuli. Alpha ERD distinguished between repeated and nonrepeated stimuli in that greater desynchronization occurred with respect to repeated stimuli. This finding indicates that alpha ERD is sensitive to the recognition of both words and faces. Unlike findings from Kimesch (1996) who suggests that only upper alpha activity indexes memory processing, however, Burgess and Gruzelier (2000) found that both lower and upper alpha bands were sensitive to memory processes involved in recognition.

Statement of the Problem

The principle focus of this dissertation was to examine the potential use of behavioral and spectral EEG responses to distinguish truthful and deceptive participants who were presented faces related and not related to enacted scenarios. Therefore, a central aim included expanding on Lawson and Pratarelli's (2000) findings by examining whether beta activity could index deception using face stimuli as an alternative to word items. The rationale for using face stimuli was that a reliable and valid measure of deception should be able to index deceptive from nondeceptive responses irrespective of stimulus type. Also, face stimuli may provide for increased applicability over words in field situations. The court's substantial reliance on eye-witness testimony is consistent with the potential use of face stimuli in the field. Therefore, an index of guilt versus innocence based on face stimuli may have applications and values in the criminal justice system.

A secondary concern was whether cognitive processes not directly related to deception accounted for differences in spectral potentials. Specifically, intrinsic motivation may account for differences between deceptive and nondeceptive groups indexed by beta potentials (Lawson & Pratarelli, 2000). To this end, a self-report measure was used to examine possible group differences in relation to intrinsic motivation.

The examination of differences between deceptive and nondeceptive participants in relation to alpha activity was expected to also provide clues to cognitive processes involved in deception. As previously stated, Burgess and Gruzelier (1997) found that alpha attenuation was correlated with performance on a face recognition task. Thus, the question arose as to whether alpha desynchronization corresponded to reaction time measures.

Design Overview and Assumptions

Participants were evenly divided into either an experimental group, which participated in a mock crime and then concealed information related to the criminal act during a lie detection test, or a contrast group, which participated in a noncrime scenario and did not conceal any information during the lie detection test. The use of scenarios to simulate criminal and noncriminal activity has recently become conventional to PDD research (Farwell & Donchin, 1991; Lawson & Pratarelli, 2000; Stelmack et al., 1996). The mock crime consisted of committing an act of espionage, while the noncrime scenario consisted of running an errand task that did not include any deceptive manipulations. Although stimulus items for both groups were identical, all participants were examined concerning the espionage case. Thus, participants in the experimental group were guilty of the crime in question while participants in the contrast group did not have any knowledge of the crime. Experimental participants were instructed to attempt to deceive the examiner concerning only stimuli related to the criminal act, while the participants in the contrast group were instructed to be truthful to all stimuli. The examiner involved in detecting deception presented himself as not having any knowledge of whether participants were deceptive or nondeceptive and all participants were directed to withhold such information from the examiner.

Stimuli consisted of three distinct types of faces relating to relevant, personally familiar, or foil (i.e., unfamiliar) stimulus categories. Relevant faces were encountered during each participant's scenario, personally familiar faces included nationally and internationally known individuals who participants verbally named and were liked, and foils which were faces unfamiliar to participants. Thus, relevant faces were gained through first-hand experience in the experiment, personally familiar faces were known to participants prior to participating in the experiment, and foil faces were unfamiliar to participants. Although the primary concern of this thesis was the examination of group differences irrespective of stimulus type, stimulus types that differed in terms of familiarity to participants was required to examine whether memory processes accounted for group differences. For example, previous studies using ERPs have found that deceptive participants can be differentiated from innocent participants by indexing whether stimuli are contained in a participant's memory set (Allen et al., 1992; Farwell & Donchin, 1991; Rosenfeld et al., 1987).

The present dissertation is based on two assumptions involving deception and the development of a tool to accurately measure this phenomenon. Deception is assumed to involve both a set of mental processes that influence the committing of a deceptive act and the deceptive act itself. Thus, mental processes related to planning strategies, determination of personal gain, and personal relevance are perhaps crucial to deception, although such processes may not occur while an individual is actually committing a deceptive act. Accordingly, a valid metric of deception should take into account both mental processes that give rise to committing a deceptive act and the knowledge of the deceptive act itself.

The present experiment accounted for mental processes associated with the deceptive act by having experimental participants participate in an espionage scenario. Anecdotal evidence suggests that espionage is commonly portrayed in television, movies, and literature as an act that involves illegal activity, secrecy, and having serious consequences if caught. These commonly held beliefs about espionage were expected to facilitate deceptive participants' mental processes in respect to beating the lie-detection test. Nondeceptive participants (contrast group) were given a scenario similar in terms of the detail of instructions, number of people the participant interacted with, and length of the scenario, but which did not contain any deceptive manipulations such as being illegal in nature, secretive, and having serious consequences if caught.

A second assumption of this study is that an accurate measurement of deception must involve the testing of first-hand knowledge. Such knowledge should have been processed at a deep level of processing because of its first-hand relevance to the individual. The levels of processing approach argues that information can be processed at different levels ranging from shallow to deeper levels of processing (Craik & Lockhart, 1972). For instance, if an individual is memorizing a list of words, counting the number of vowels in each word may be considered a shallow level of processing while actually acting out the words would be considered a deeper level of processing. In field situations, participants who try to deceive a lie-detection test are considered to process relevant information at a deep level because the information is personally relevant, being caught could have severe consequences, and the information was gained through first-hand experience. The current thesis attempted to approximate field situations by having participants experience relevant information first-hand using the mock crime and errand scenarios.

The current study is important in that it expands the existing knowledge base concerning the use of EEG as a tool for the detection of concealed information. This was done by examining whether a spectral indicator of deception exists. PDD tools used in the detection of deception assume that changes in physiological reactions indicate deception. However, physiological reactions can be influenced by a number of cognitive, motor, and emotional factors. Thus, PDD tools such as the polygraph are not necessarily good indicators of a specific cognitive process generated by the central nervous system. EEGs tend to have more accurate and reliable measures of deception than current PDD measures. However, the use of spectral EEG as a tool for the detection of deceit remains unclear.

The chief problem with detecting deceit is that deception is a conscious and intentional process under most formal circumstances. Therefore, deceit can be controlled by the individual. Outside the laboratory, participants can choose or not choose to cooperate with tools and examiners who detect deception. Therefore, an indirect means of detecting concealed information is required to more accurately detect deception. Although the detection of a general state of arousal representing cognitive processes underlying deception is not a direct measure of deceit, the use of spectral EEG to detect deception may be an improvement over current PDD and ERP measures.

Hypotheses

The study described in subsequent chapters of this paper examined the effect of concealed information on behavioral and spectral beta components, the utility of using faces as stimuli for indexing deception versus nondeception, and potential group differences in relation to intrinsic motivation, task demands, and semantic demands. This experiment was designed to evaluate several hypotheses suggested by previous literature on differences between individuals who conceal or do not conceal information associated with the recognition of faces. These hypotheses are described below.

Based on findings from Lawson and Pratarelli (2000), the experimental group was expected to respond faster and more accurately than the contrast group to all stimuli except for personally familiar items.

H_1: Response time to relevant and foil stimuli will differentiate experimental from contrast groups.

H_2: Response accuracy to relevant and foil stimuli will differentiate experimental from contrast groups.

Lawson and Pratarelli's (2000) findings that deceptive participants were faster and more accurate than innocent participants to all stimuli except for personally familiar words may have been due to differences between groups in terms of intrinsic motivation. However, the self-report measure used in their quasi-replication experiment which indexed intrinsic motivation did not support this explanation.

H_3: No significant group differences will be found in relation to intrinsic motivation.

Burgess and Gruzelier (2000) found that alpha activity indexed differences between familiar and unfamiliar faces. Also, previous research has established that alpha activity is sensitive to differences in task demands (Burgess & Gruzelier, 1997; Klimesch, 1999). Because experimental participants in the present study had the added cognitive task of concealing information that contrast participants did not, it was expected that group differences would be found in relation to stimuli.

H_4: Differences in alpha amplitude will distinguish between stimulus types in terms of familiar and unfamiliar faces.

H_5: Significant interaction between group and stimulus type will be found in relation to alpha amplitude that indexes the increased task demands required for deceptive responses over innocent responses.

Based on the findings from Lawson and Pratarelli (2000), differences between experimental and contrast groups measured at the beta bandwidth were expected in terms of anterior versus posterior processing.

H_6: Frequency of the high peak amplitude in the beta bandwidth will differentiate experimental from contrast groups irrespective of stimulus type in terms of anterior versus posterior processing recorded at midline electrode sites.

H_7: Frequency of the trough amplitude in the beta bandwidth will differentiate experimental from contrast groups irrespective of stimulus type in terms of anterior versus posterior processing recorded at sagittal electrode sites.

Based on hemispheric differences found in relation to the acquisition and recognition of faces, it was expected that hemispheric differences in the beta bandwidth would be found in relation to stimuli that were familiar and unfamiliar to participants (Burgess & Gruzelier, 1997).

H_8: Frequency and amplitude measures of the beta bandwidth will differentiate stimulus types in terms of familiarity and unfamiliarity at posterior electrode sites in the right hemisphere.

Chapter II: Method

Participants

All participants were verbally solicited from Oklahoma State University undergraduate classes. The final sample consisted of 42 participants who ranged between 18 and 33 years of age, were right handed, had English as their first language, normal or corrected-to-normal vision, no history of neurological disorders or learning disabilities, and no prior experience in a mock crime scenario or with lie detectors. Data for an additional five participants were discarded due to incomplete data, one as a result of experimenter error and four as a result of electrode impedances above five Kohms. Participants read an information form concerning the study and completed an attached consent form indicating their agreement to participate in the study. Participants were evenly divided, but randomly assigned, to the experimental group or the contrast group. The experimental group consisted of 21 participants (15 women and 6 men, mean age = 20.3) who enacted a mock crime involving espionage. The contrast group consisted of 21 participants (15 women and 6 men, mean age = 19.8) who performed a scenario involving an errand that did not contain any deceptive manipulations. Participants received extra-credit for their participation in the study.

Estimation of the number of participants needed to achieve a four to one ratio of power (1 – beta) to alpha was determined to be 42 participants by a power analysis procedure for factorial Analysis of Variance (ANOVA) designs using partial omega squares to calculate Cohen's (1977) *f* statistic (Keppel, 1991). With respect to the methodological and design similarities between Lawson and Pratarelli (2000) and the present study, proposed hypotheses reflecting significant findings from their study were used to estimate partial omega square values (Table 1). These effect size values were then used to determine Cohen's *f* statistic and the appropriate sample size for this proposed study (Table 2).

A primary concern of the current thesis was to examine whether group differences exist averaged over all stimuli for anterior versus posterior processing (i.e., hypotheses five and six). The significant effects of group by midline of midline high frequency data and group by electrode of sagittal low frequency data corresponded to this concern and the power analysis revealed that n = 21 and n = 14 respectively, were required to detect these differences at alpha = 0.05 and power = 0.80 (Lawson & Pratarelli, 2000).

A secondary concern of this thesis was to examine attentional differences between groups (i.e., hypotheses one and two). To this end, the significant effects of group for response accuracy data, group by stimulus for response accuracy data, and group by stimulus for reaction time data corresponded to this concern and the power analysis revealed that n = 6, n = 11, and n = 11 respectively, were required to detect these differences at alpha = 0.05 and power = 0.80 (Lawson & Pratarelli, 2000).

With respect to the proposed hypotheses addressed, the number of participants required per group was 21, thus indicating a sample size of 42.

Face Stimuli

Stimuli consisted of 12 full faces (face and hair down to the chin), each corresponding to a different individual, and taken from photographs or downloaded from various sites on the internet. The rationale for using 12 stimuli (i.e., four faces per stimulus category) was based on pilot testing which indicated that participants could encounter four faces during their respective scenarios without compromising the deceptive

Table 1

Significant Effects from Lawson and Pratarelli (2000) Used in Determining Sample Size

Statistical Design: 2 (group) x 4 (stimulus) x 3 (midline) ANOVA of midline high frequency data

Significant Effect	F value	$\hat{o}^2_{\text{effect}}$	$\hat{o}^2_{\text{error}}$	W^2
group x midline	$F(2, 36) = 5.69, p. = .007$	.278	1.78	.135

- 2 (group) x 4 (stimulus) x 2 (electrode) x 2 (hemisphere) ANOVA of sagittal low frequency data

Significant Effect	F value	$\hat{o}^2_{\text{effect}}$	$\hat{o}^2_{\text{error}}$	W^2
Group x electrode	$F(1, 18) = 14.48, p. =.001$	1.39	4.12	.252

- 2 (group) x 4 (stimulus) ANOVA of behavioral reaction time data

Significant Effect	F value	$\hat{o}^2_{\text{effect}}$	$\hat{o}^2_{\text{error}}$	W^2
group x stimulus	$F(3, 54) = 8.29, p. < .001$	294	1074.49	.215

- 2 (group) x 4 (stimulus) ANOVA of behavioral response accuracy data

Significant Effect	F value	$\hat{o}^2_{\text{effect}}$	$\hat{o}^2_{\text{error}}$	W^2
Group	$F(1, 18) = 24.47, p. < .001$	16.3	13.91	.540
group x stimulus	$F(3, 54) = 9.07, p. < .001$	2.18	7.21	.232

Table 2

Estimation of Sample Size Using Partial Omega Square Values from Lawson and Pratarelli (2000)

Statistical Design:

- 2 (group) x 4 (stimulus) x 3 (midline) ANOVA of midline high frequency data

Significant Effect	*f* statistic	N	N
group x midline	.40	21	42

- 2 (group) x 4 (stimulus) x 2 (electrode) x 2 (hemisphere) ANOVA of sagittal low frequency data

Significant Effect	*f* statistic	N	N
group x electrode	0.58	14	28

- 2 (group) x 4 (stimulus) ANOVA of behavioral reaction time data

Significant Effect	*f* value	N	N
group x stimulus	0.52	11	22

- 2 (group) x 4 (stimulus) ANOVA of behavioral response accuracy data

Significant Effect	*f* statistic	N	N
Group	1.1	6	12
group x stimulus	0.55	11	22

or errand nature of these scenarios.

Each image was of a frontal view, and reflected the individual's natural color without any unnatural distinctive features (e.g. jewelry, excessive make-up). All face images were digitized, if required, and placed on the hard disk of an IBM-compatible Pentium 90 microcomputer. In order to insure that all face images were equal in detail and clarity, only digital originals that had a resolution greater than 100 pixels per square inch were edited for stimulus presentation. All images were digitally edited to remove any background details and features below the chin. The size of each face image was four inches in height and width with a resolution of 100 pixels per square inch. Edited face images were presented in five-second intervals (stimulus duration = 2000 ms, inter-stimulus interval = 3000 ms) on a standard computer monitor with 16 bit true color graphics. The stimuli displaced approximately three and a half degrees of visual angle to the left and right of the center screen.

Face categories included four relevant faces relating to the participants' scenarios, four personally familiar faces (relating only to the participant's personal preferences and derived from a naming/preference task), and four foil faces (not related to the participant or any scenario). Each stimulus was presented five times corresponding to five blocks. All faces in each block were randomly placed and presented in serial order that remained consistent for every participant.

A naming/preference task was used to gather and norm personally familiar faces from each participant and consisted of 15 different nationally and internationally famous faces including musicians, actors/actresses, and politicians. Each potentially personally familiar face was presented on a computer monitor that was consistent with the experimental presentation of stimuli. Upon examination of each face, participants were asked whether the face was personally familiar, the name of the individual corresponding to the face, whether the individual was personally liked or disliked, and how influential this person had been in his/her life. Four face images that were correctly identified and had high likeness/influence ratings were used as personally familiar stimuli (see Appendix A).

Apparatus for Behavioral Data

Behavioral data were collected by instructing participants to press either a yes or no button on a computer keyboard as a function of the familiarity of a stimulus. An IBM-compatible Pentium microcomputer collected the response time and response accuracy to each stimulus.

Materials for Self – Report Data

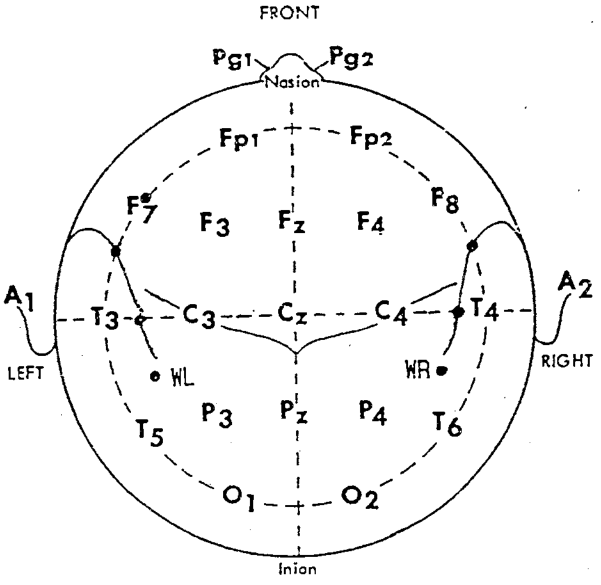
A modified version of the Work Preference Inventory 7th edition (WPI) was used to examine differential effects of intrinsic and extrinsic motivation (Amabile, Hill, Hennessey, & Tighe, 1994). The WPI is a 30 item self-report measure that indexes general task oriented levels of intrinsic and extrinsic motivation. It includes secondary scales including *challenge* and *enjoyment* that reflect intrinsic motivation and *compensation*, and *outward* reflecting extrinsic motivation. The questions in this inventory were modified to reflect only motivational orientations that occurred during the experiment, and three additional questions (i.e., How interesting was the experiment?, How enjoyable was the experiment?, How willing would you be to come back voluntarily in the future to participate in a similar experiment that contains a scenario?) were added that had been found to index intrinsic motivation and behavioral measures (Reeve & Cole, 1987). All questions were answered using a five point Likert scale (ranging from *not at all* to *extremely*). The modified version of the WPI, named the Experiment Interest Survey, appears in Appendix B.

Apparatus for Spectral EEG Data

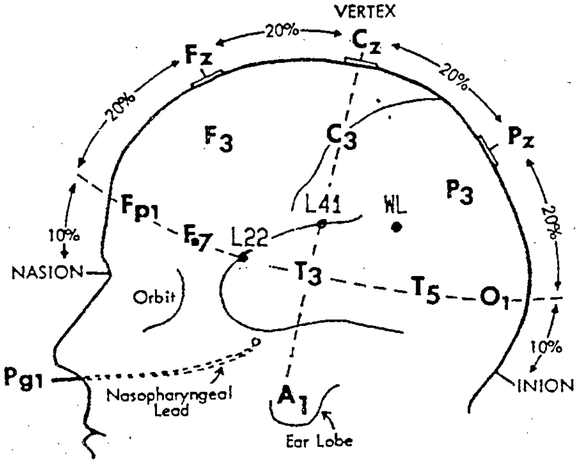
Participants were fitted with a stretch forming electrode cap (Electro-Cap, International, Inc., Eaton, OH) imbedded with 11 EEG tin electrodes. The recording sites included the International 10/20 system locations (Figure 2) Fz, Cz, Pz, and Oz along the midline, F7, F8, T3, T4, T5, and T6 sagittal of the midline, and C3 and C4 mid-sagittal of the midline. An additional electrode used for eye-artifact rejection was placed below the left eye. All electrode impedances were below five Kohms and variances between the reference electrodes were no more than 10 percent.

EEG amplification filter constants were set at 1.0 and 100 Hz. This prevents the aliasing of physiological activity at frequencies beyond the cutoff. EEG were recorded, digitized, and analyzed using the WinDaq software (DataQ Instruments, Inc., Akron, OH). Individualized artifact rejection thresholds were calibrated so that any trials containing eye blinks or excessive horizontal eye movement were rejected prior to analysis. Trials which passed artifact rejection criteria were sorted by trial-type condition. For every participant, three randomly selected artifact-free, 1,960 millisecond epochs for each condition underwent a DFT analysis. The DFT yielded plots of power for each participant in each condition and for each electrode site. Frequency and amplitude data ranging from 5 Hz to 35 Hz were recorded to encompass lower alpha, upper alpha, and beta bandwidths.

The frequency windows for the lower alpha, upper alpha, and beta bands were determined individually based on alpha mean peak frequency ‘f(i)’ which is the frequency, averaged over an entire epoch (five seconds) and all recording sites, with the highest



TOP OF HEAD



LEFT SIDE OF HEAD

Figure 2. Scalp Recording Montage. The electrode configuration adheres to the International 10 / 20 system.

amplitude ranging from eight to 13 Hz for each participant 'i'. Using f(i) as the cut-off point, and a bandwidth of 2.5 Hz, the lower alpha band was defined as f(i) – 2.5 Hz and the upper alpha band was defined as f(i) + 2.5 Hz. The beta band was defined as ranging from the next frequency point beyond the upper alpha band cutoff to 30 Hz.

Procedures

Each participant individually participated in the experiment by enacting a scenario on the first day and then performing a computerized task during EEG data collection on the second.

Day 1

The experimental (espionage) group was given a key and told they need to proceed to another location in a nearby building, enter by the side door, walk down a corridor, locate the correct room, and then enter the room while making sure that no person was in the room prior to entrance. Once in the room, participants proceeded to a set of locked file drawers said to contain various blueprints of objects (missile diagrams and schematics) and possibly pictures that identified informants (two face images). They were instructed to unlock the file drawer, locate and remove any documents or pictures located in a file named "DOOM Project," photograph them with a small pocket camera given to them by the trainer, return the documents to their correct folder, turn off the lights in the room, and make certain that the door was locked when they left. From that location, they exited the building the same way that they entered.

As participants exited the corridor, they encountered another confederate, posing as one of the janitors, who asked them casually why they were in the building after-hours. Participants had been coached not to reveal to anyone what they were doing, or where they were going. (Any participants who had would have been ejected from the study because they were more likely to have violated other aspects of their instructions as well.) From the building, participants proceeded to the park located across the street, and waited by the pond for a man wearing a black baseball cap with a soccer ball emblem. They approached the man in the black cap and briefly and quietly made a verbal exchange indicating their identities. The man then took possession of the camera and gave the participant a sealed envelope containing a note. Participants then returned to the laboratory for a debriefing with the trainer, producing the note as evidence that they completed the scenario.

The contrast (errand) group was given a pen, manila envelope, piece of paper, and told to enter the library using the north entrance. Once in the library, participants walked to an elevator located in the center of the building and went to the third floor. Participants then walked out into the third floor and proceeded to find a pre-specified journal and book. Participants opened the journal and wrote down the title of an article written by a specific author and examined a face of an individual from a book and wrote down the individual's hair color, gender, and expression. While the participants were finding the journal and book, they were approached by a confederate, who, after making a prespecified verbal exchange, gave each participant a face image which they placed in the manila envelope.

Once the participants finished writing down the title, name, and face features on the piece of paper, they placed the pen and paper in the manila envelope along with the face image. Participants then sealed the envelope and exited the library the same way they entered it. (Any participants who had not sealed the manila envelope would have been ejected from the study because they were more likely to have violated other aspects of their instructions as well.) After leaving the library, participants proceeded to the clock tower where they approached by a man in a blue shirt holding a basketball and briefly and quietly made a verbal exchange that indicated their identities. The man then took possession of the manila envelope and gave that participant a backpack. Participants then returned to the laboratory for a debriefing with the trainer, producing the backpack as evidence that they completed the scenario.

The debriefing for all participants involved the same individual who initially trained them for the scenario, and covered the main events, i.e., which documents were actually photographed for experimental participants or which titles were actually written down for contrast participants. This procedure ensured that the important times, places, people, objects, and sequence of events were experienced by the participant, thereby becoming part of his/her knowledge base. Participants were then told that they would be connected to a lie detection device the following day by an examiner who did not know which scenario they had conducted. All participants were told not to discuss the previously performed scenario with the examiner the following day. The errand participants were told to be truthful about scenario (relevant faces) related information in the experiment the next day, while the espionage participants were told to conceal information related to their scenario. Participants were given a practice session on Day 1 to insure that they understood what the trial sequence will look like the following day.

Day 2

All participants were fitted with a stretch forming electrode cap. Participants were then seated in a comfortable recording chair approximately three feet from a 17-inch color monitor attached to the stimulus computer. The stimulus computer was also linked to the

EEG recording system for the purpose of triggering the digitizer. EEG signals were continuously digitized and event triggers were placed on the EEG that referenced stimulus onset. A two-button keyboard was given to participants who then received instructions to enter manual responses concerning the familiarity of each target stimulus. Participants were also told to take a break whenever the phrase "break time" was presented on the monitor screen and to press any key when ready to continue to the next stimulus block.

The stimulus set of 12 faces was presented in five blocks for a total of 60 trials. The 12 stimuli were presented one at a time, each for a duration of two seconds. Each face was presented five times in order to insure that following EEG artifact rejection (e.g., eye blinks), three trials remained per stimulus category for data averaging. Each face was either relevant or irrelevant to the participant's enacted scenario. For instance, the face images encountered during a participant's scenario were considered relevant while the face images unknown to the participant (i.e., foils) and faces of personally familiar individuals were considered irrelevant. The "personally familiar" face images were drawn from the naming/preference task given the previous day. The items in this category, therefore, were specific knowledge provided by the participant. All participants received the same sequence of randomized stimuli with their own personally familiar face images inserted at the appropriate location in the sequence.

Following the presentation of face stimuli, the electrode cap was removed and any remaining electrode gel to the scalp was removed with a moist paper towel. Participants were then requested to complete the Experimental Interest Inventory related to motivational orientation during the experiment. Following completion of this self - report measure, participants were debriefed about the experiment.

Behavioral Data Analysis

The behavioral data (reaction time, response accuracy) were analyzed using a 2 X 3 Multivariate Analysis of Variance (MANOVA) design for two groups (experimental, contrast) and three stimulus categories (scenario, personally familiar, foil) with repeated measures on the latter variable.

Self – Report Data Analysis

The self – report data were analyzed using a 2 X 2 ANOVA design for two groups (experimental, contrast) and two motivation categories (intrinsic, extrinsic) with repeated measures on the latter variable.

Calculation and Analysis of ERD

Alpha data for each epoch and each of the 12 channels were digitally band-pass filtered, squared, and averaged separately for each experimental condition and for each participant. Based on these data, Event Related Desynchronization (ERD) values were calculated using a procedure originally developed by Pfurtscheller and Aranibar (1977). ERD is defined as the percentage of a decrease or increase in alpha-band power which occurs during a test interval as compared to a reference interval: ERD % = {[(alpha power, reference interval) – (alpha power, test interval)] / (alpha power, reference interval)} × 100. Positive ERD values indicated a state of alpha desynchronization or alpha suppression while negative ERD values reflected a state of alpha synchronization (increased alpha power).

The reference interval consisted of the 1,960 ms immediately preceding the presentation of each stimulus while the test interval consisted of the 1,960 ms epoch following stimulus onset. This epoch was used because there should be no stimulus related activity occurring immediately prior to stimulus onset. In addition, because expectancy effects are (a) constant, and (b) limited to about 500 ms before stimulus onset, the additional 1,460 ms of cognitive inactivity should result in a reasonably clean reference epoch.

ERD data which reflected the same participant, alpha type, condition, and electrode site were averaged together and analyzed using ANOVA procedures. For midline sites, a 2 X 2 X 3 X 4 ANOVA design was analyzed for two groups (experimental, contrast), two alpha types (lower, upper), three stimulus categories (relevant, personally familiar, foil), and four electrode sites (Fz, Cz, Pz, Oz) with repeated measures on the latter three variables. For sagittal sites, a 2 X 2 X 3 X 3 X 2 ANOVA design was analyzed for two groups (experimental, contrast), two alpha types (lower, upper), three stimulus categories (relevant, personally familiar, foil), three electrode areas (F7 and F8 frontal, T3 and T4 anterior-temporal, T5 and T6 posterior-temporal), and two hemisphere areas (F7, T3, and T5 in the left hemisphere, F8, T4, and T6 in the right hemisphere) with repeated measures on the latter four variables. For mid-sagittal sites, a 2 X 2 X 3 X 2 ANOVA design was analyzed for two groups (experimental, contrast), two alpha types (lower, upper), three stimulus categories (relevant, personally familiar, foil), and two hemisphere areas (C3 in the left hemisphere, C4 in the right hemisphere) with repeated measures on the latter three variables.

Calculation of Beta Dependent Variables

Analysis of the Beta bandwidth was similar to Lawson and Pratarelli (2000) and is outlined as follows. Four dependent variables including high peak frequency (PF), peak amplitude (PA), low peak (trough) frequency (TF), and trough amplitude (TA) were collected. PF and TF were defined as the frequency points (in Hz) within the beta range with the highest and lowest power respectively. PA and TA (in dB) corresponded to the power of the PF and TF respectively.

Data which reflected the same participant, condition, and electrode site were averaged together and analyzed using a MANOVA procedure. For midline sites corresponding to each dependent variable within the MANOVA procedure, a 2 X 3 X 4 ANOVA design was analyzed for two groups (experimental, contrast), three stimulus categories (relevant, personally familiar, foil), and four electrode sites (Fz, Cz, Pz, Oz) with repeated measures on the latter two variables. For sagittal sites corresponding to each dependent variable within the MANOVA procedure, a 2 X 3 X 3 X 2 ANOVA design was analyzed for two groups (experimental, contrast), three stimulus categories (relevant, personally familiar, foil), three electrode areas (F7 and F8 frontal, T3 and T4 anterior-temporal, T5 and T6 posterior-temporal), and two hemisphere areas (F7, T3, and T5 in the left hemisphere, F8, T4, and T6 in the right hemisphere) with repeated measures on the latter three variables. For midsagittal sites corresponding to each dependent variable within the MANOVA procedure, a 2 X 3 X 2 ANOVA design was analyzed for two groups (experimental, contrast), three stimulus categories (relevant, personally familiar, foil), and two hemisphere areas (C3 in the left hemisphere, C4 in the right hemisphere) with repeated measures on the latter two variables.

Chapter III: Results

Data were initially checked for violations of normality using frequency distributions. Also, Geisser - Greenhouse corrected F values are reported for all ANOVA tests with greater than two degrees of freedom. To allow for brevity and comprehension, results illustrated in tables and figures are located, respectively, at the end of the chapter. Due to the large number of potential effects and post-hocs, only those effects that were significant are reported.

Behavioral Analyses

To test hypotheses one and two, a 2 X 2 X 3 MANOVA design for two groups (experimental, contrast), two dependent variables (reaction time, response accuracy), and three stimulus categories (relevant, personally familiar, foil) with repeated measures on the latter two variables was examined. Results are listed in Table 3. In light of the significant MANOVA, the behavioral data were analyzed using a 2 X 3 ANOVA design for two groups (experimental, contrast) by three stimulus categories (relevant, personally familiar, foil) with repeated measures on the latter variable. This model was applied to reaction time (RT) as well as response accuracy (RA) data.

The RT data revealed a significant main effect of stimulus, $\underline{F}$ (2, 80) = 24.72, $\underline{p} < .0005$, with milliseconds being the dependent variable (Figure 3). Post-hoc pair-wise comparisons using Neuman-Keuls indicated that participants responded slower to foil stimuli ($\underline{p} < .01$) than both relevant and personally familiar stimuli. A significant group by stimulus interaction effect, $\underline{F}$ (2, 80) = 5.56, $\underline{p} < .02$, was also found using RT data (Figure 4). Post-hoc pair-wise comparisons using Simple Main Effects revealed that experimental participants responded faster to both relevant and foil stimuli than contrast participants ($p < .01$).

Results of the RA data revealed a significant main effect of stimulus, F (2, 80) = 3.44, $p = .05$, with average number of correct responses out of 20 being the dependent variable (Figure 5). Post-hoc pair-wise comparisons indicated that participants more accurately responded to relevant stimuli than foil stimuli ($p < .05$). Also, a marginal group by stimulus interaction effect, F (2, 80) = 2.93, $p = .074$, was found (Figure 6). Due to the marginal differences found, no post-hoc pair-wise comparisons were performed for this interaction.

Self-Report Data Analysis

The self-report data (relating to hypothesis three) were analyzed using a 2 X 2 ANOVA design for two groups (experimental, contrast) and two motivation categories (intrinsic, extrinsic) with repeated measures on the latter variable. Results of the self-report data revealed a significant main effect of motivation, F (1, 40) = 35.250, $p < .0005$ (Figure 7). Participants reported that they were more intrinsically motivated than extrinsically motivated. No significant interactions were found.

Alpha ERD Analyses

To test hypotheses four and five, separate ANOVAs were examined in relation to midline, sagittal, and midsagittal electrode sites. A 2 X 2 X 3 X 4 ANOVA, having a group factor (experimental, contrast), two repeated measures for alpha type (lower, upper), three repeated measures for stimulus category (relevant, personally familiar, foil), and four repeated measures for electrode location (Fz, Cz, Pz, Oz) was applied to the midline spectral ERD data.

No significant main effects were found. However, significant interaction effects of alpha type by electrode, F (3, 120) = 6.19, p < .002 (Figure 8), and group by alpha type by stimulus, F (2,80) = 3.81, p < .03 (Figure 9), were found. For the alpha type by electrode interaction, post-hoc pair-wise comparisons revealed that lower alpha had higher event-related desynchronization (ERD) values than upper alpha at Pz, whereas upper alpha had higher ERD values than lower alpha at Oz. For the group by alpha type by stimulus interaction, post-hoc pair-wise comparisons revealed two group differences. Experimental participants were more desynchronized at lower alpha for foil stimuli than contrast participants. Also, experimental participants were more desynchronized at upper alpha for relevant stimuli than contrast participants.

A 2 X 2 X 3 X 3 X 2 ANOVA, having a group factor (experimental, contrast), two repeated measures for alpha type (lower, upper), three repeated measures for stimulus category (relevant, personally familiar, foil), three repeated measures for electrode area (frontal, anterior-temporal, posterior-temporal), and two repeated measures for hemisphere (left, right) was applied to the sagittal alpha ERD data.

A significant main effect of electrode area, F (2, 80) = 18.69, p < .0005, for pooled data across hemispheres was found (Figure 10). Post-hoc pair-wise comparisons revealed that the posterior-temporal electrodes were more desynchronized than both the frontal and anterior temporal electrodes. Also, a marginal stimulus by electrode area interaction effect, F (4, 160) = 2.47, p = .06, was found (Figure 11). No post-hoc pair-wise comparisons were performed for the marginal interaction.

A 2 X 2 X 3 X 2 ANOVA, having a group factor (experimental, contrast), two repeated measures for alpha type (lower, upper), three repeated measures for stimulus category (relevant, personally familiar, foil), and two repeated measures for hemisphere (left, right) was applied to the mid-sagittal alpha ERD data.

No significant main effects were found. However, a significant alpha type by hemisphere interaction effect, F (1, 40) = 4.10, p = .05 (Figure 12), was found. Post-hoc pair-wise comparisons revealed that lower alpha was more desynchronized than upper alpha in the right hemisphere.

Spectral Beta Analyses

For midline beta data (relating to hypotheses six and eight), a 2 X 4 X 3 X 4 MANOVA design for two groups (experimental, contrast), four dependent measures (high peak frequency (PF), peak amplitude (PA), low peak (trough) frequency (TF), trough amplitude (TA)), three stimulus categories (relevant, personally familiar, foil), and four electrode sites (Fz, Cz, Pz, Oz) with repeated measures on the latter three variables was examined. Results are listed in Table 4. For sagittal beta data (relating to hypotheses seven and eight), a 2 X 4 X 3 X 3 X 2 MANOVA design for two groups (experimental, contrast), four dependent measures (PF, PA, TF, TA), three stimulus categories (relevant, personally familiar, foil), three electrode areas (frontal, anterior-temporal, posterior-temporal), and two hemispheres (left, right) with repeated measures on the latter four variables was examined. Results are listed in Table 5. For mid-sagittal beta data (relating to hypothesis eight), a 2 X 4 X 3 X 2 MANOVA design for two groups (experimental, contrast), four dependent measures (PF, PA, TF, TA), three stimulus categories (relevant, personally familiar, foil), and two hemispheres (left, right) with repeated measures on the latter three variables was examined. Results are listed in Table 6. In light of these significant MANOVAs, the beta data were analyzed using ANOVA designs.

A 2 X 3 X 4 ANOVA, having a group factor (experimental, contrast), three repeated measures for stimulus category (relevant, personally familiar, foil), and four repeated measures for electrode location (Fz, Cz, Pz, Oz) was applied to the midline beta data. This model was separately applied to four dependent variables: PF, PA, TF, and TA.

No significant results were found for midline PA, TF, or TA beta data. However, a significant main effect of electrode, F (3, 120) = 5.47, $p < .005$, was found for beta PF data, with a metric of average frequency of the high peaks (Figure 13). Post-hoc pair-wise comparisons revealed that Oz had a significantly ($p < .01$) higher PF than Pz.

A 2 X 3 X 3 X 2 ANOVA, having a group factor (experimental, contrast), three repeated measures for stimulus category (relevant, personally familiar, foil), three repeated measures for electrode area (frontal, anterior-temporal, posterior-temporal), and repeated measures for hemisphere (left vs. right), was applied to the sagittal beta data. This model was separately applied to all four dependent variables: PF, PA, TF, and TA.

For the sagittal PF beta data, a significant main effect of electrode area, F (2, 80) = 18.15, $p < .0005$, was found (Figure 14). Post-hoc pair-wise comparisons revealed that the PF of the posterior-temporal electrodes was lower than the PF of both anterior-temporal and frontal electrodes ($p < .01$).

For the sagittal PA beta data, significant main effects were found for stimulus, F (2, 80) = 4.81, $p < .02$ (Figure 15), and for electrode area, F (2, 80) = 28.76, $p < .0005$ (Figure 16). Post-hoc pair-wise comparisons of the main effect of stimulus revealed that foil stimuli had a significantly higher PA ($p < .05$) than both relevant and personally familiar stimuli. Post-hoc pair-wise comparisons of the main effect of electrode revealed that all electrode areas significantly differed ($p < .01$) from each other.

For the sagittal TF beta data, significant main effects were found for stimulus, F (2, 80) = 3.214, $p < .05$ (Figure 17), and for electrode area, F (2, 80) = 14.31, $p < .0005$ (Figure 18). Post-hoc pair-wise comparisons of the main effect of stimulus revealed that relevant stimuli had a significantly higher TF than personally familiar stimuli ($p < .05$). Post-hoc pair-wise comparisons of the main effect of electrode revealed that all electrode areas significantly differed ($p < .01$) from each other.

For the sagittal TA beta data, a significant main effect of electrode area, F (2, 80) = 16.34, $p < .0005$, was found (Figure 19). Post-hoc pair-wise comparisons of the main effect of electrode revealed that anterior-temporal electrodes had a higher TA than both frontal and posterior-temporal electrodes ($p < .01$). A significant group by hemisphere interaction, F (1, 40) = 4.15, $p < .05$ was found (Figure 20). Post-hoc pair-wise comparisons indicated that the experimental group showed a lower TA in the right hemisphere than the contrast group. This significant group by hemisphere interaction was not indicated by the MANOVA (Table 5).

A 2 X 3 X 2 ANOVA, having a group factor (experimental, contrast), three repeated measures for stimulus category (relevant, personally familiar, foil), and repeated measures for hemisphere (left vs. right), was applied to the mid-sagittal (i.e., C3, C4) beta data. This model was separately applied to all four dependent variables: PF, PA, TF, and TA.

No significant main effects were found with mid-sagittal PF beta data. However, a significant stimulus by hemisphere interaction effect, F (2, 80) = 3.55, $p < .04$, was found

(Figure 21). Post-hoc pair-wise comparisons revealed that relevant items had a higher PF in the left hemisphere, whereas foil items had a higher PF in the right hemisphere. This significant interaction was not indicated by the MANOVA (Table 6).

For mid-sagittal PA beta data, a significant main effect of hemisphere, $\underline{F}$ (1, 40) = 10.519, $\underline{p} < .005$, was found (Figure 22). PAs were lateralized to the right. This significant main effect was not indicated by the MANOVA (Table 6). No interaction effects were found.

No significant effects were found for mid-sagittal TF beta data. However, a significant main effect of stimulus, $\underline{F}$ (2, 80) = 3.65, $\underline{p} < .04$, was found for mid-sagittal TA beta data (Figure 23). Post-hoc pair-wise comparisons revealed that relevant stimuli had a higher TA than foils ($\underline{p} < .05$). This significant main effect of stimulus not indicated by the MANOVA (Table 6). No interaction effects were found.

Table 3

MANOVA for Behavioral Data

Source	df	F	p
Dependent Variables (DVs)	(1, 40)	1294.04	< .0005
Stimulus (S)	(2, 39)	15.84	< .0005
Group (G) x S	(2, 39)	9.30	< .0005
DVs x S	(2, 39)	15.81	< .0005
G x DVs x S	(2, 39)	9.44	< .0005

Note. Only marginal and significant effects are reported. All values enclosed in parentheses represent between and within degrees of freedom respectively. F values and probabilities are consistent for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistics.

Table 4

MANOVA for Midline Beta Data

Source	Df	F	p
Dependent Variables (DVs)	(3, 38)	4260.33	< .0005
Electrode (E)	(3, 38)	2.69	= .06
DVs x Stimulus (S) x E	(18, 23)	3.27	< .005
Group x DVs x S x E	(18, 23)	1.93	= .07

Note. Only marginal and significant effects are reported. All values enclosed in parentheses represent between and within degrees of freedom respectively. F values and probabilities are consistent for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistics.

Table 5

MANOVA for Sagittal Beta Data

Source	Df	F	p
Dependent Variables (DVs)	(3, 38)	8429.80	< .0005
Stimulus (S)	(2, 39)	2.45	= .099
Electrode (E)	(2, 39)	19.76	< .0005
DVs x S	(6, 35)	2.52	< .04
DVs x E	(6, 35)	19.54	< .0005

Note. Only marginal and significant effects are reported. All values enclosed in parentheses represent between and within degrees of freedom respectively. F values and probabilities are consistent for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistics.

Table 6

MANOVA for Mid-sagittal Beta Data

Source	df	F	p
Dependent Variables (DVs)	(3, 38)	3544.31	< .0005
Hemisphere x Group	(1, 40)	2.918	= .095

Note. Only marginal and significant effects are reported. All values enclosed in parentheses represent between and within degrees of freedom respectively. F values and probabilities are consistent for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistics.

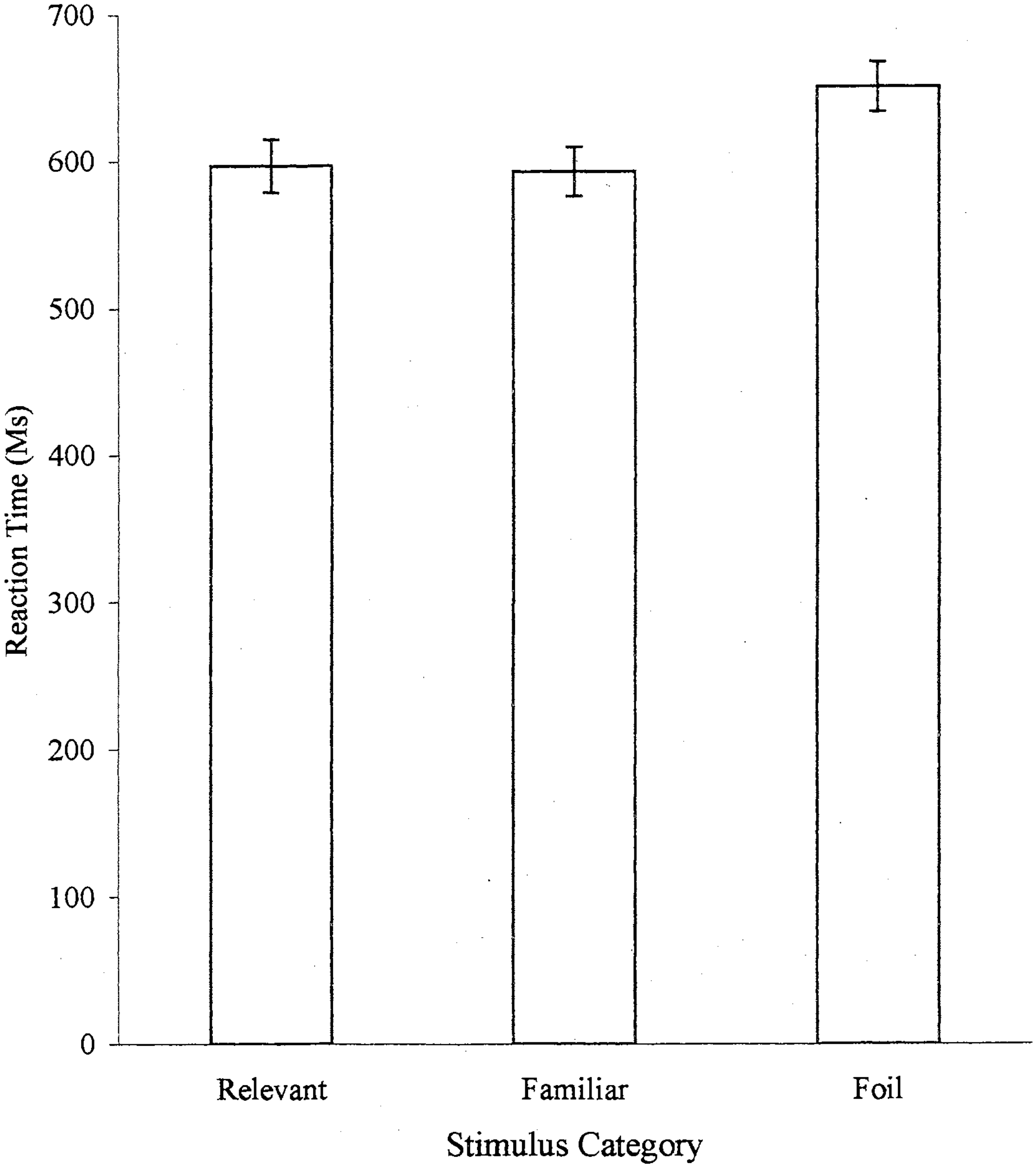


Figure 3. Main effect of stimulus for RT data. Error bars represent one standard error of the mean.

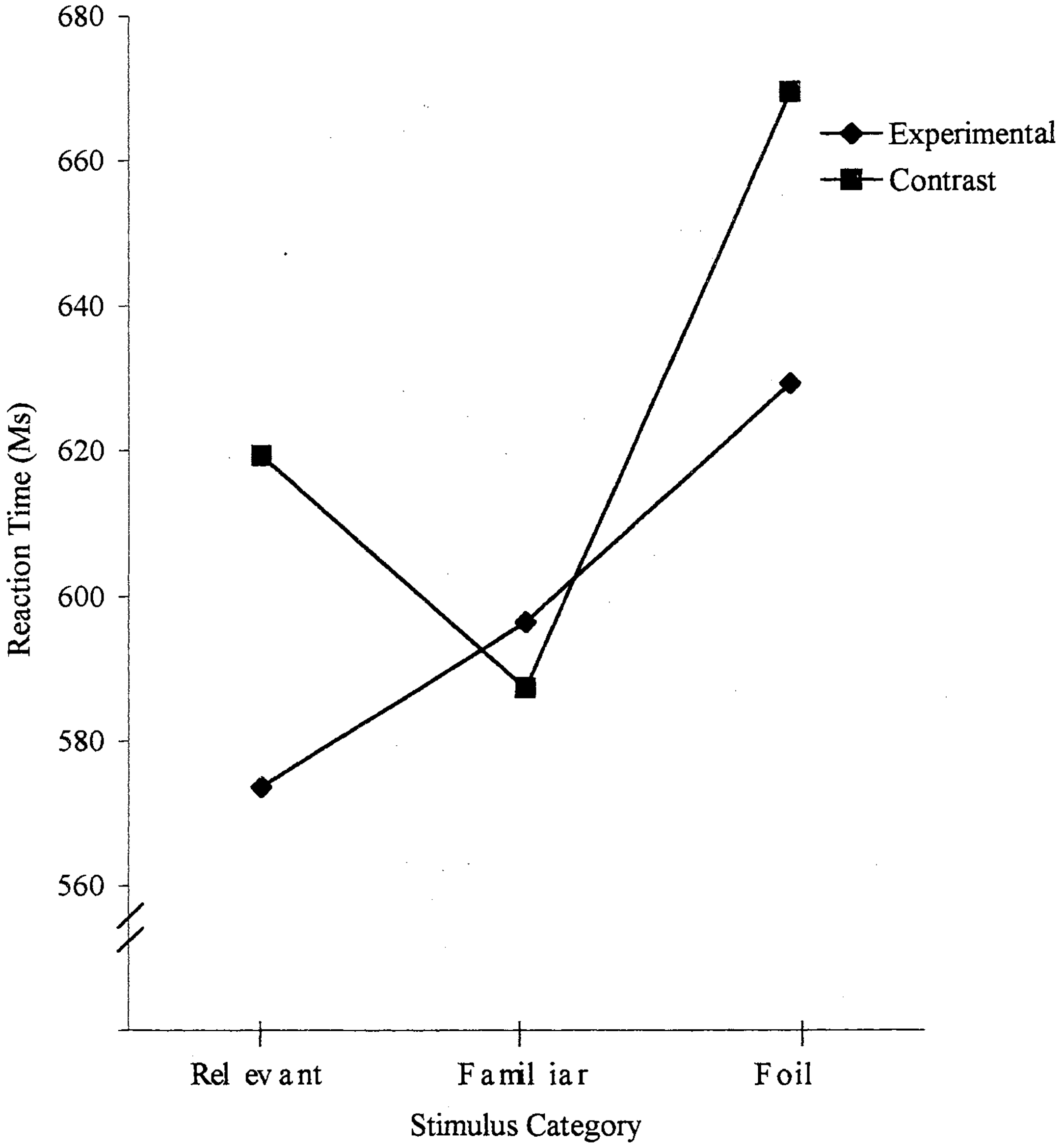


Figure 4. Effect of group by stimulus for RT data.

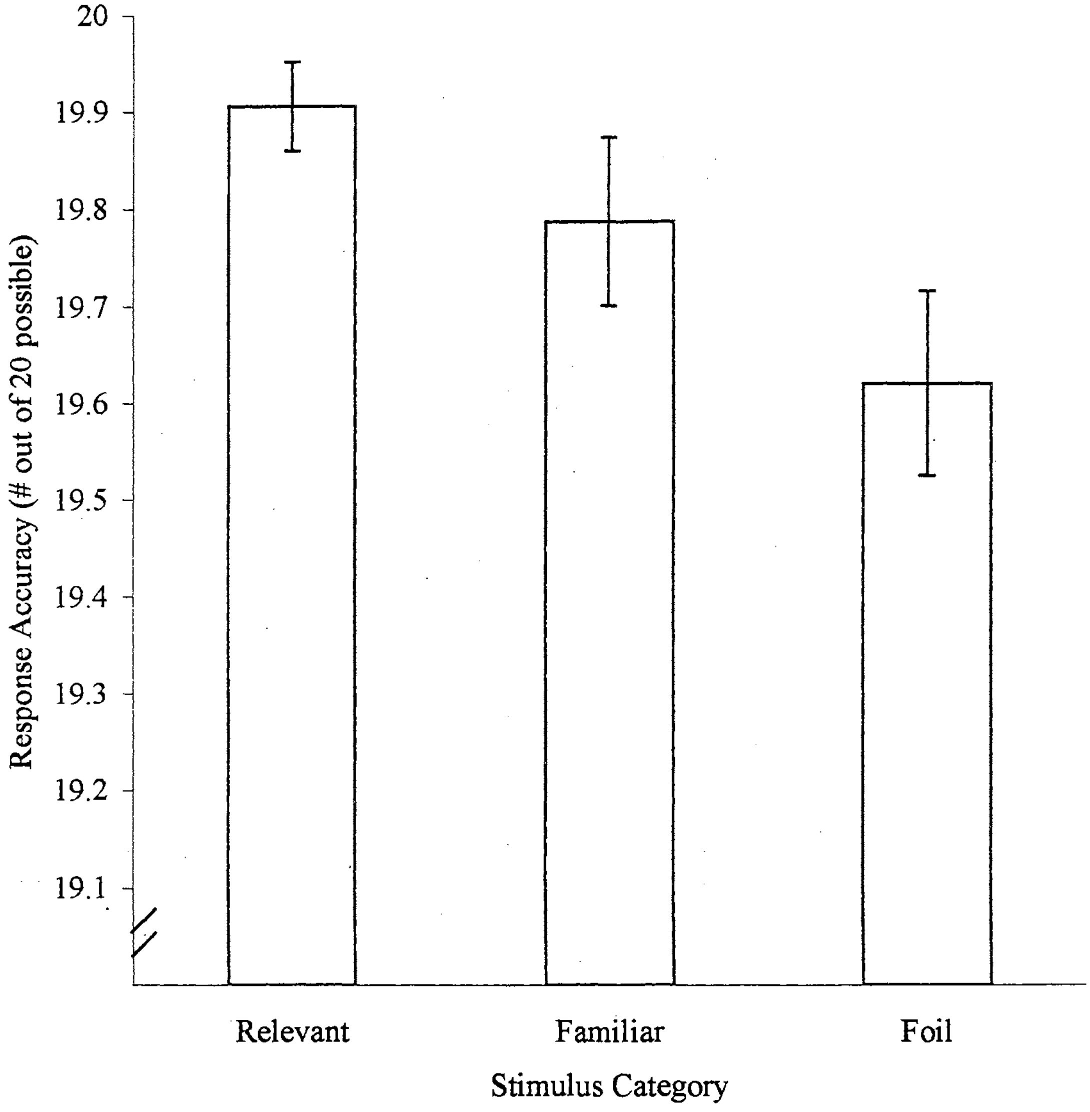


Figure 5. Main effect of stimulus for RA data. Error bars represent one standard error of the mean.

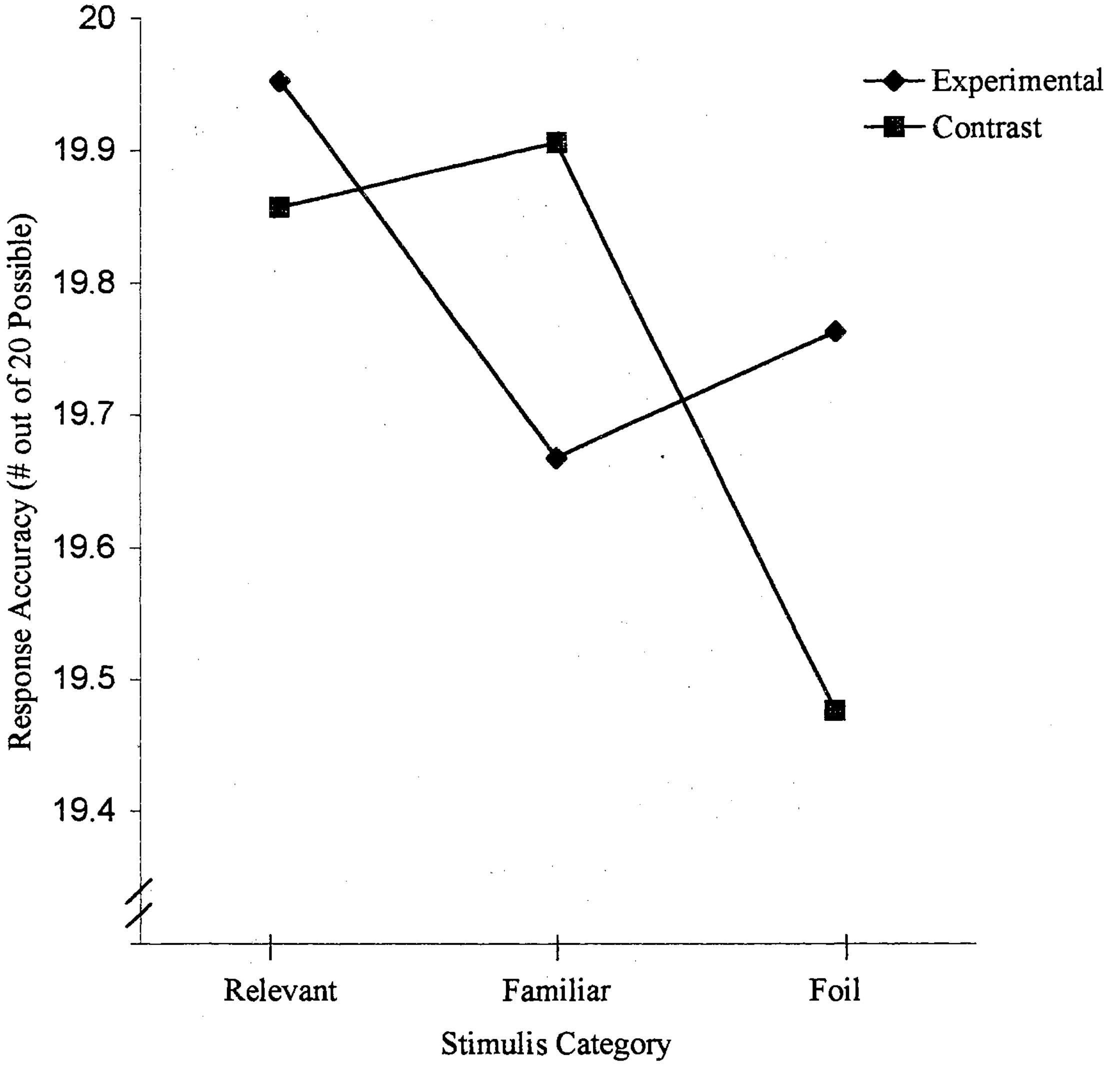


Figure 6. Marginal effect of group by stimulus for RA data.

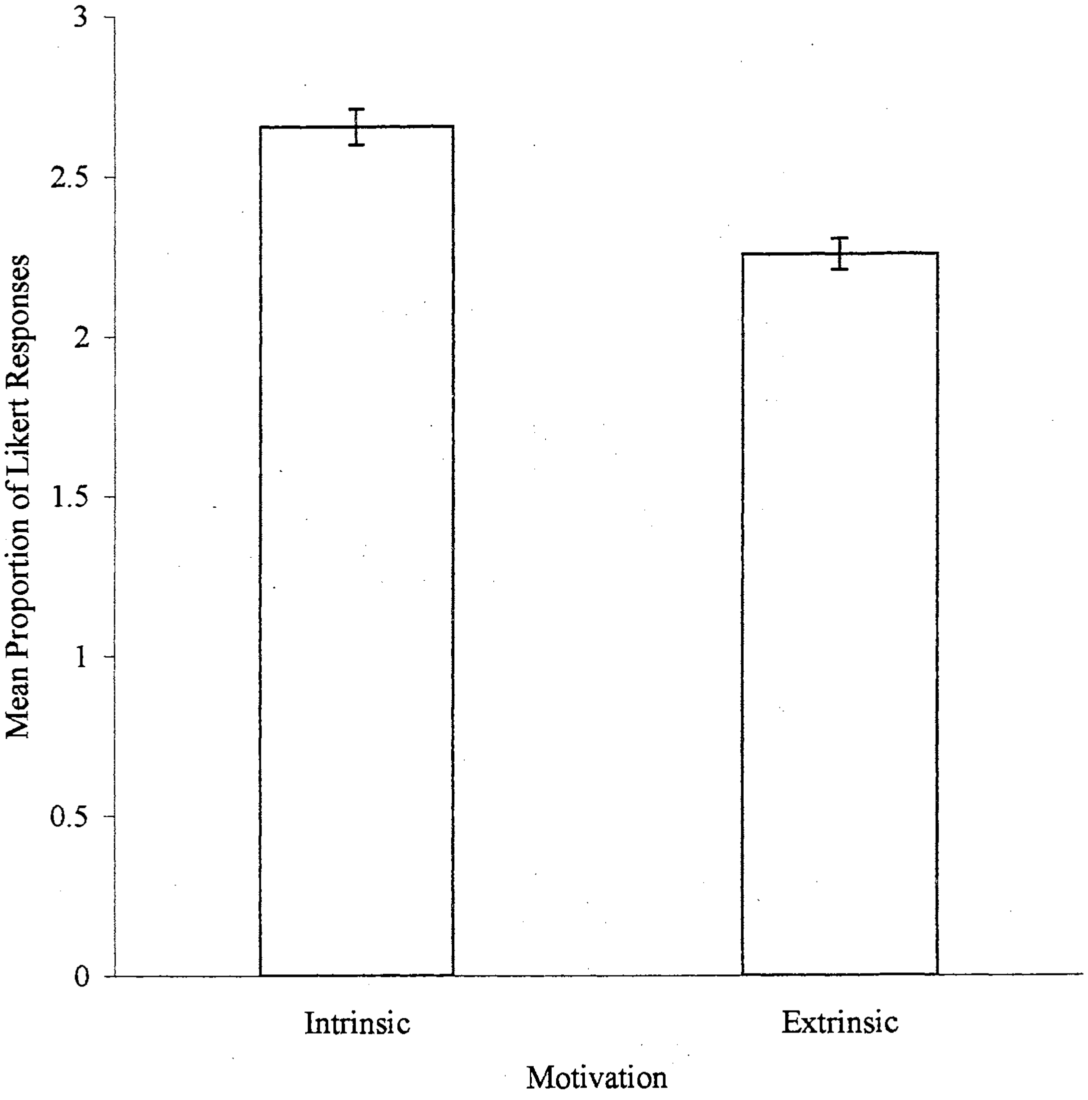


Figure 7. Main effect of motivation. Error bars represent one standard error of the mean.

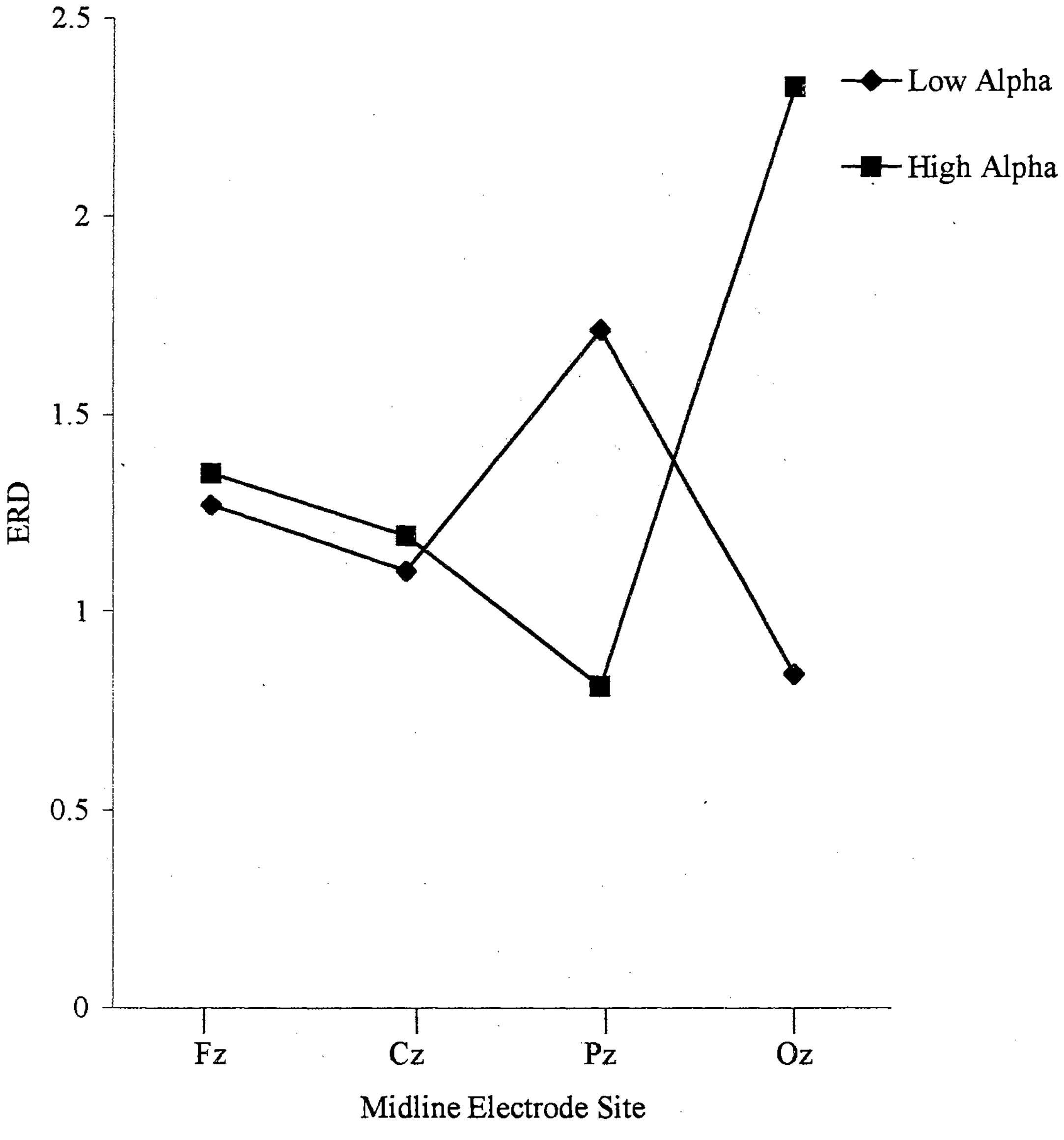


Figure 8. Effect of alpha type by electrode for midline alpha ERD data.

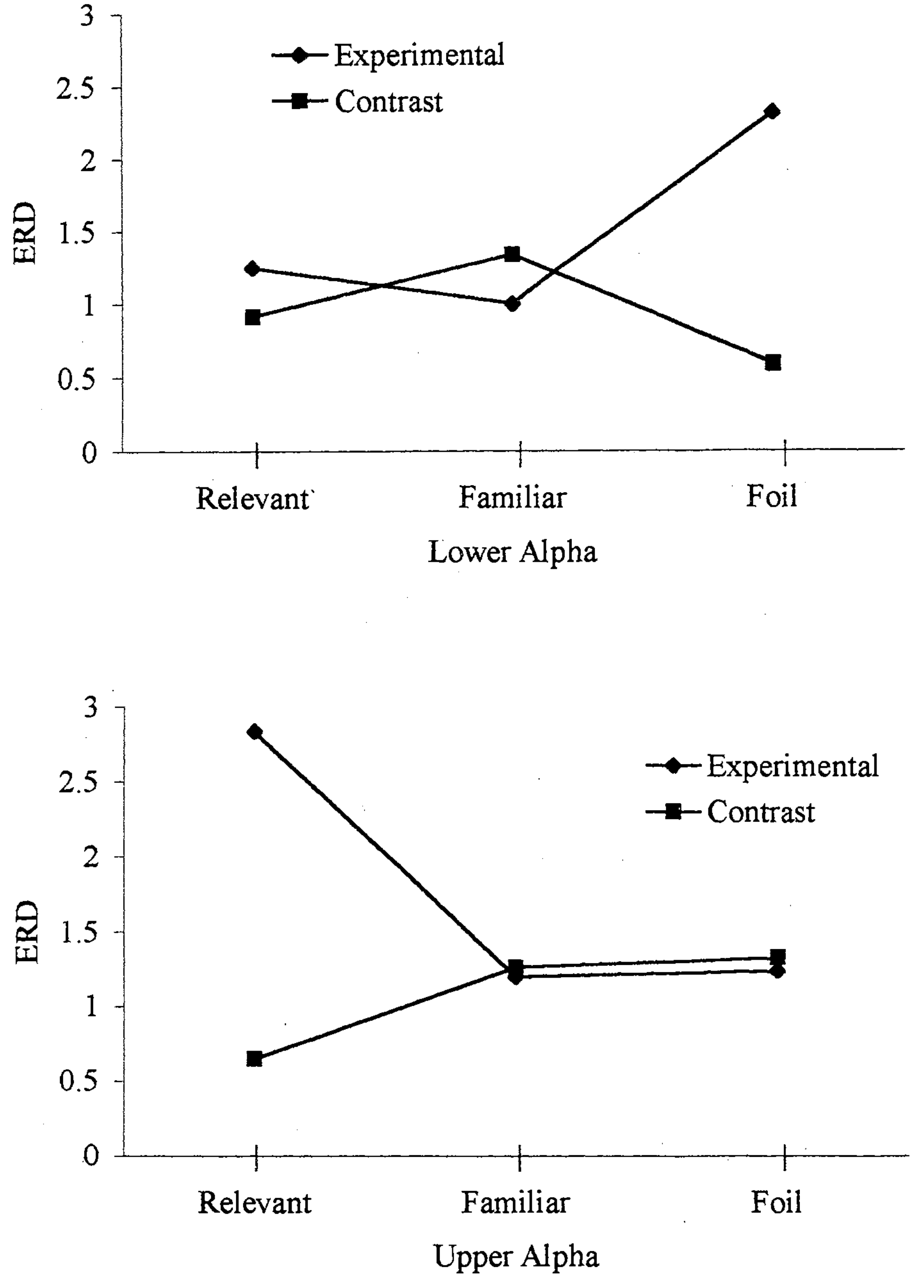


Figure 9. Effect of group by alpha type by stimulus category for midline alpha ERD data. The experimental group exhibited increased desynchronization for foil faces at lower alpha frequencies (see top panel) and for relevant faces at upper alpha frequencies (see bottom panel).

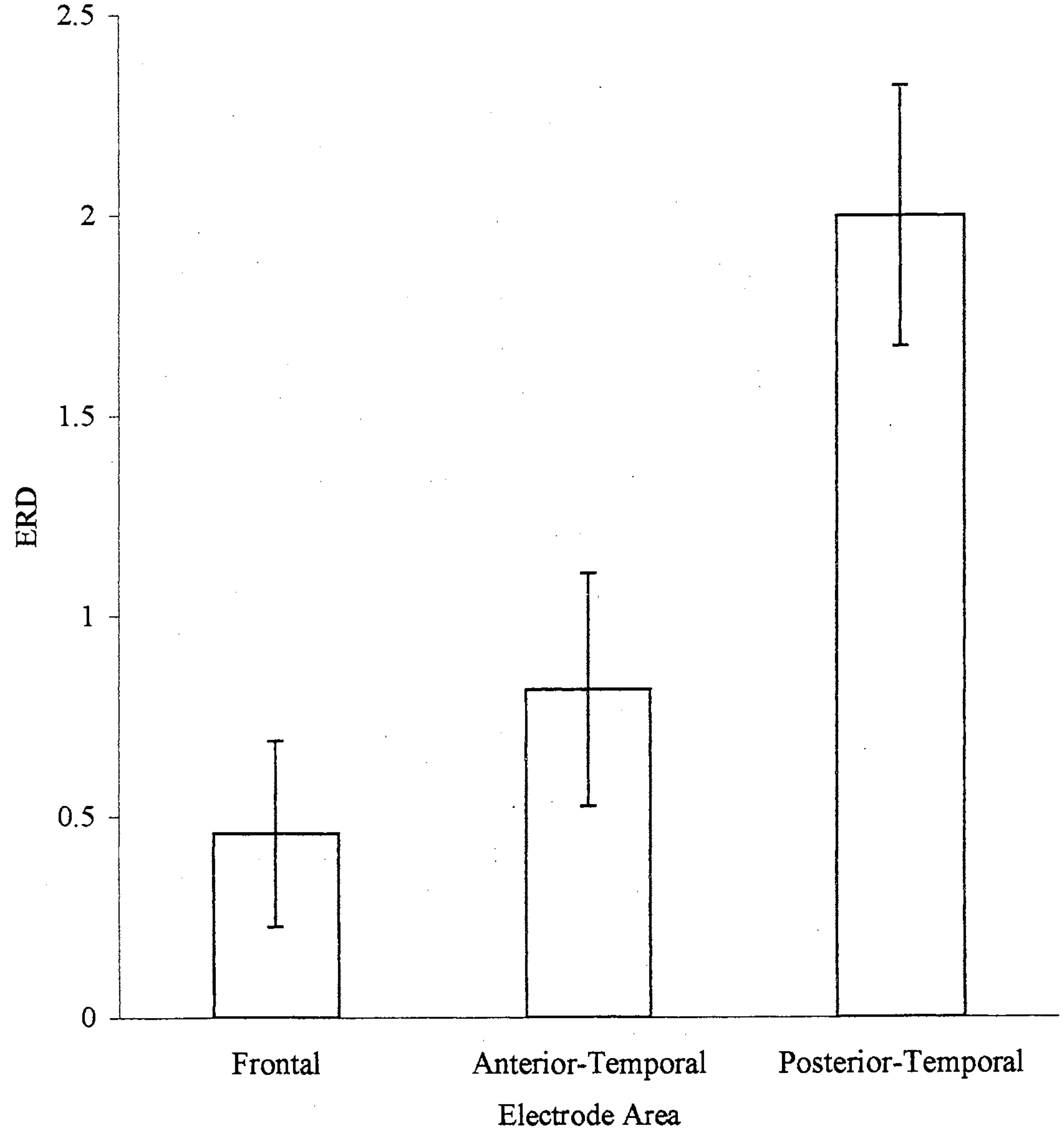


Figure 10. Main effect of electrode for sagittal alpha ERD data. Error bars represent one standard error of the mean.

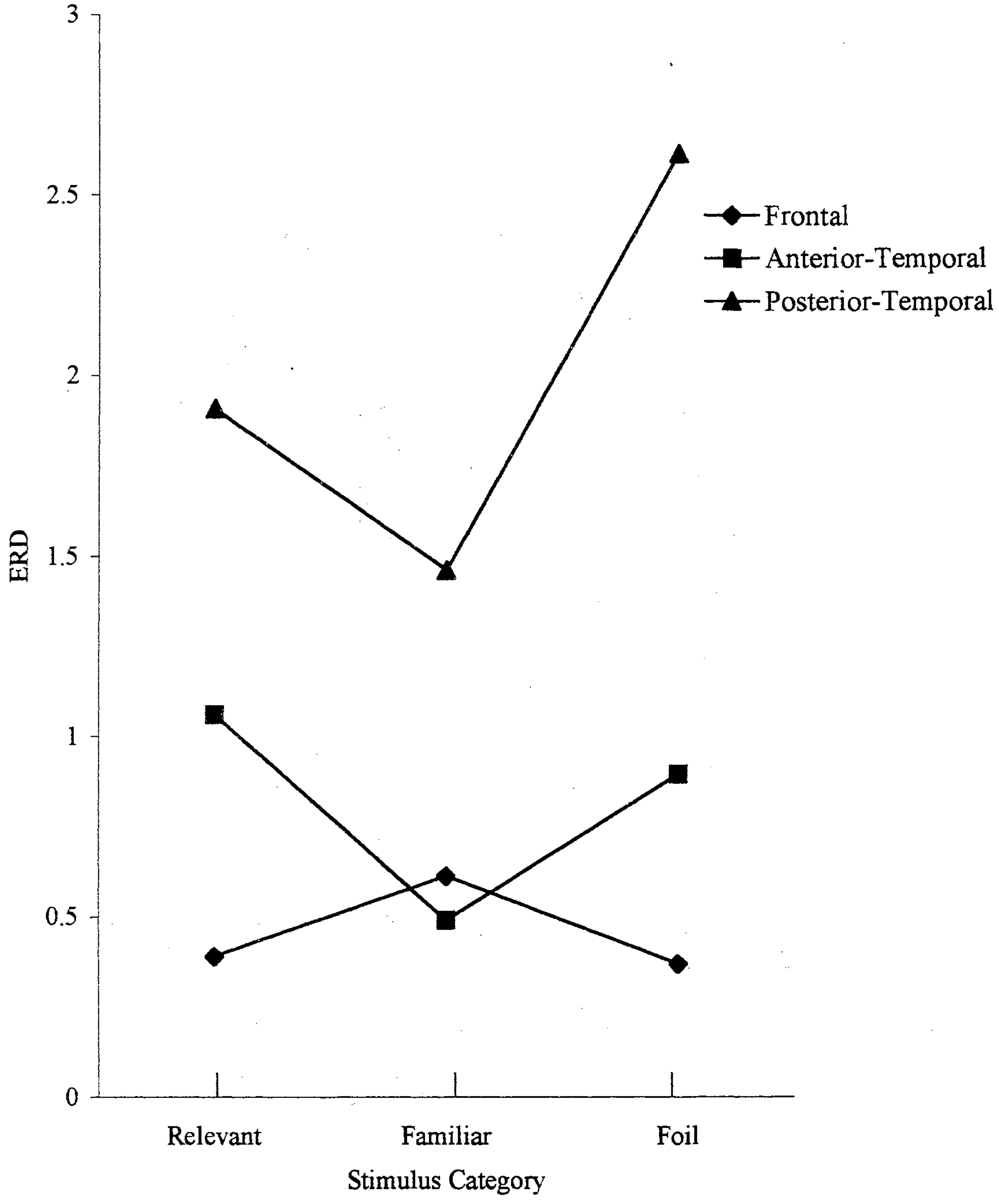


Figure 11. Marginal effect of stimulus category by electrode area for sagittal alpha ERD data.

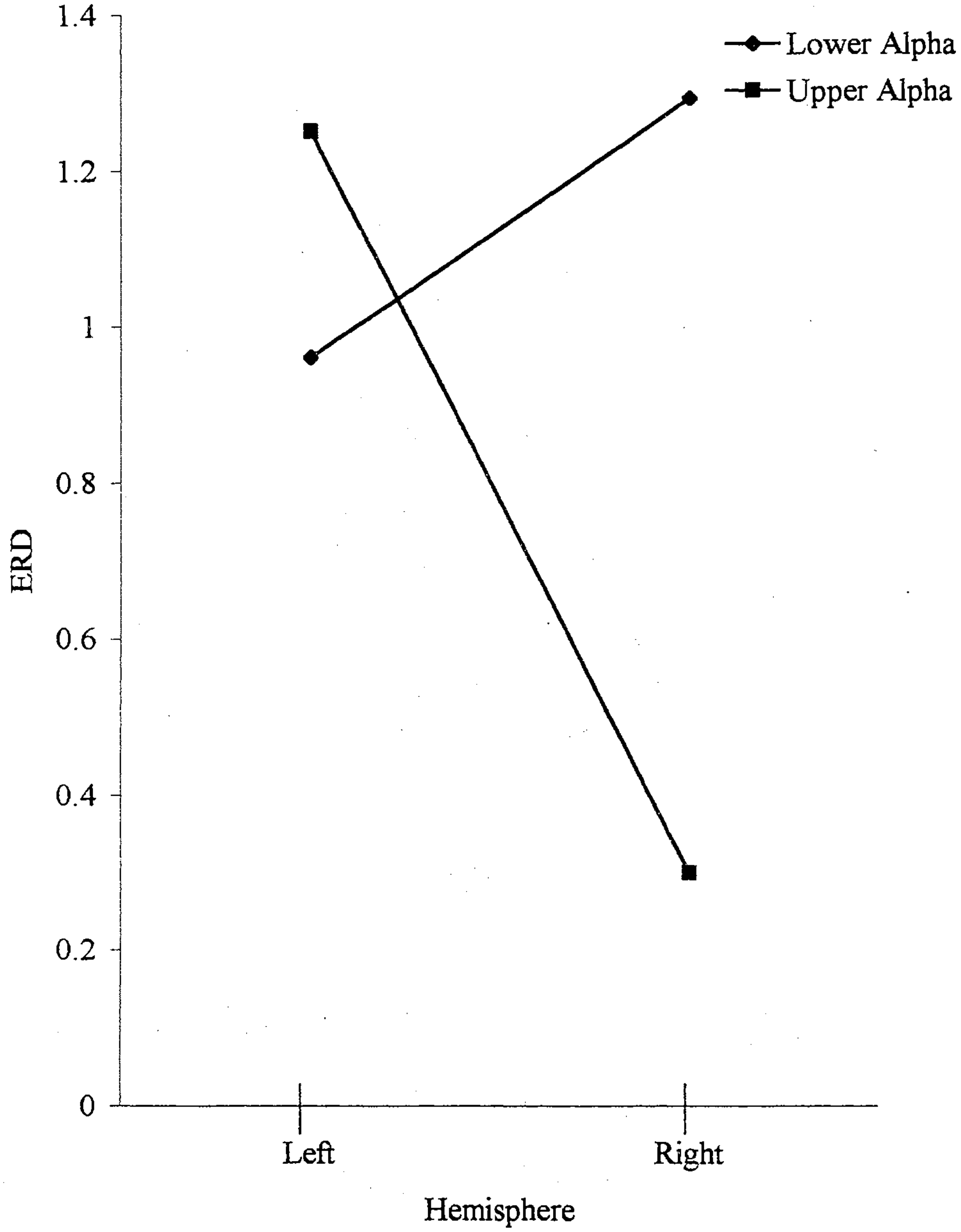


Figure 12. Effect of alpha by hemisphere for alpha ERD data

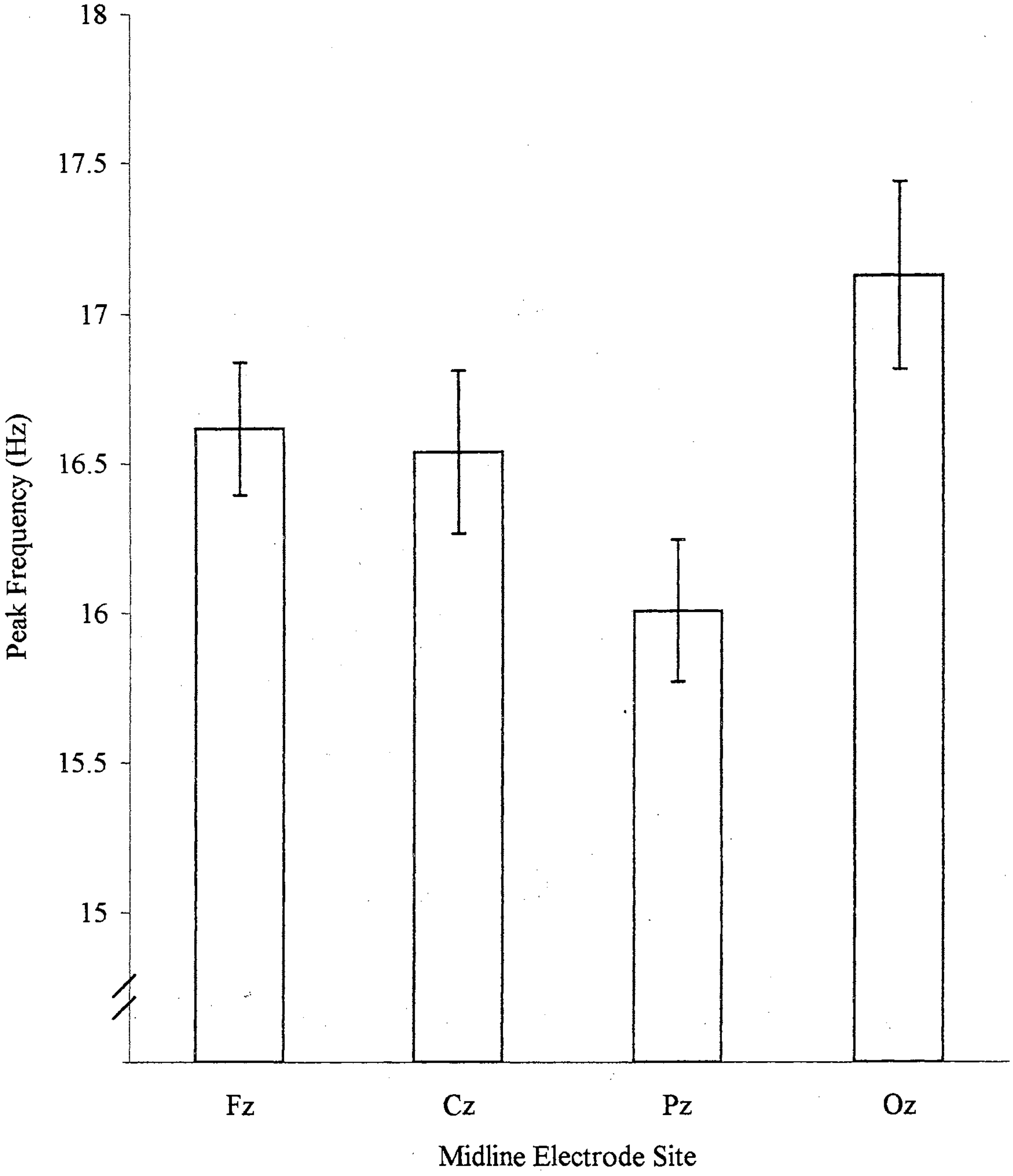


Figure 13. Main effect of electrode for midline PF beta data. Error bars represent one standard error of the mean.

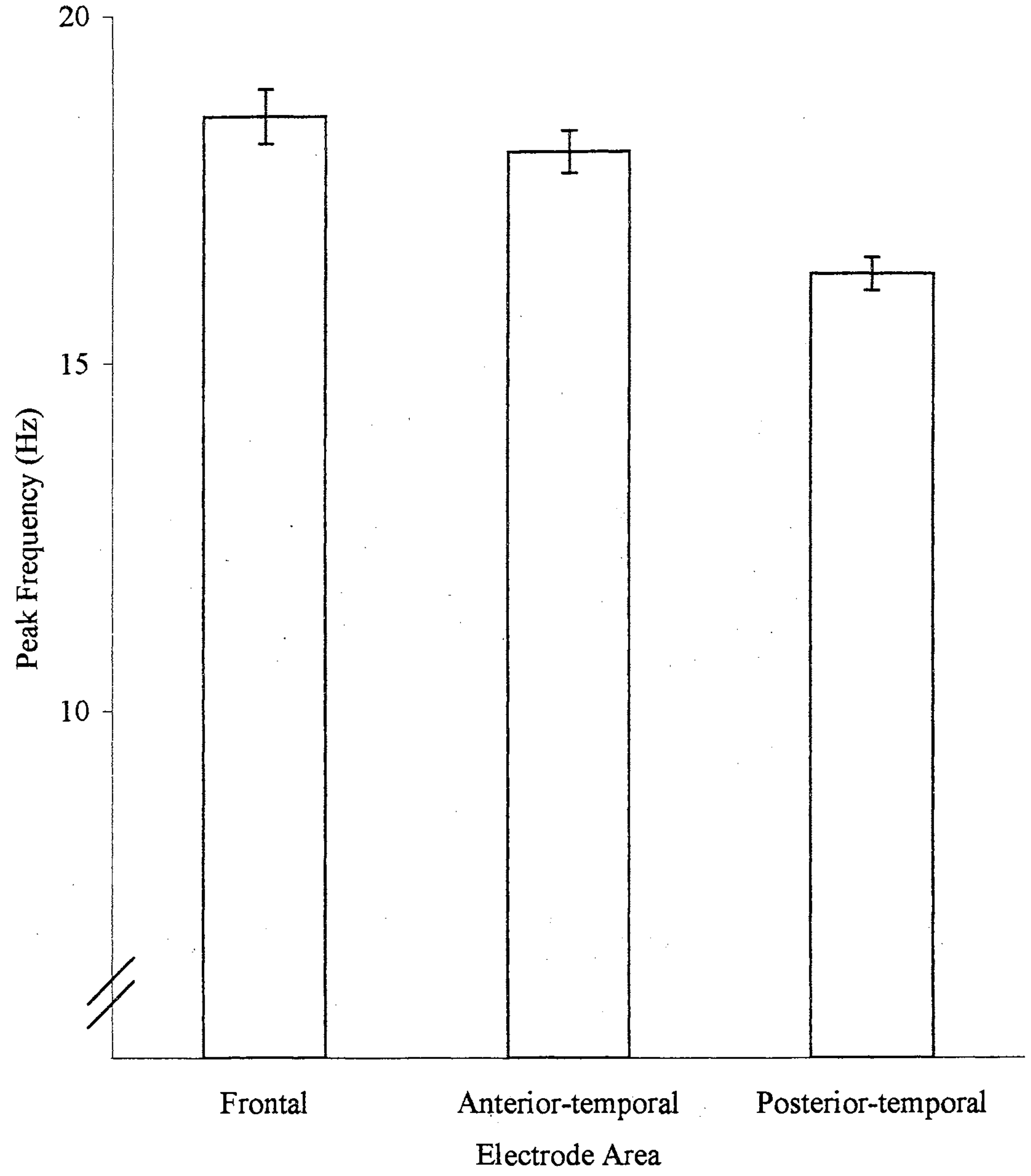


Figure 14. Main effect of electrode for sagittal PF beta data. Error bars represent one standard error of the mean.

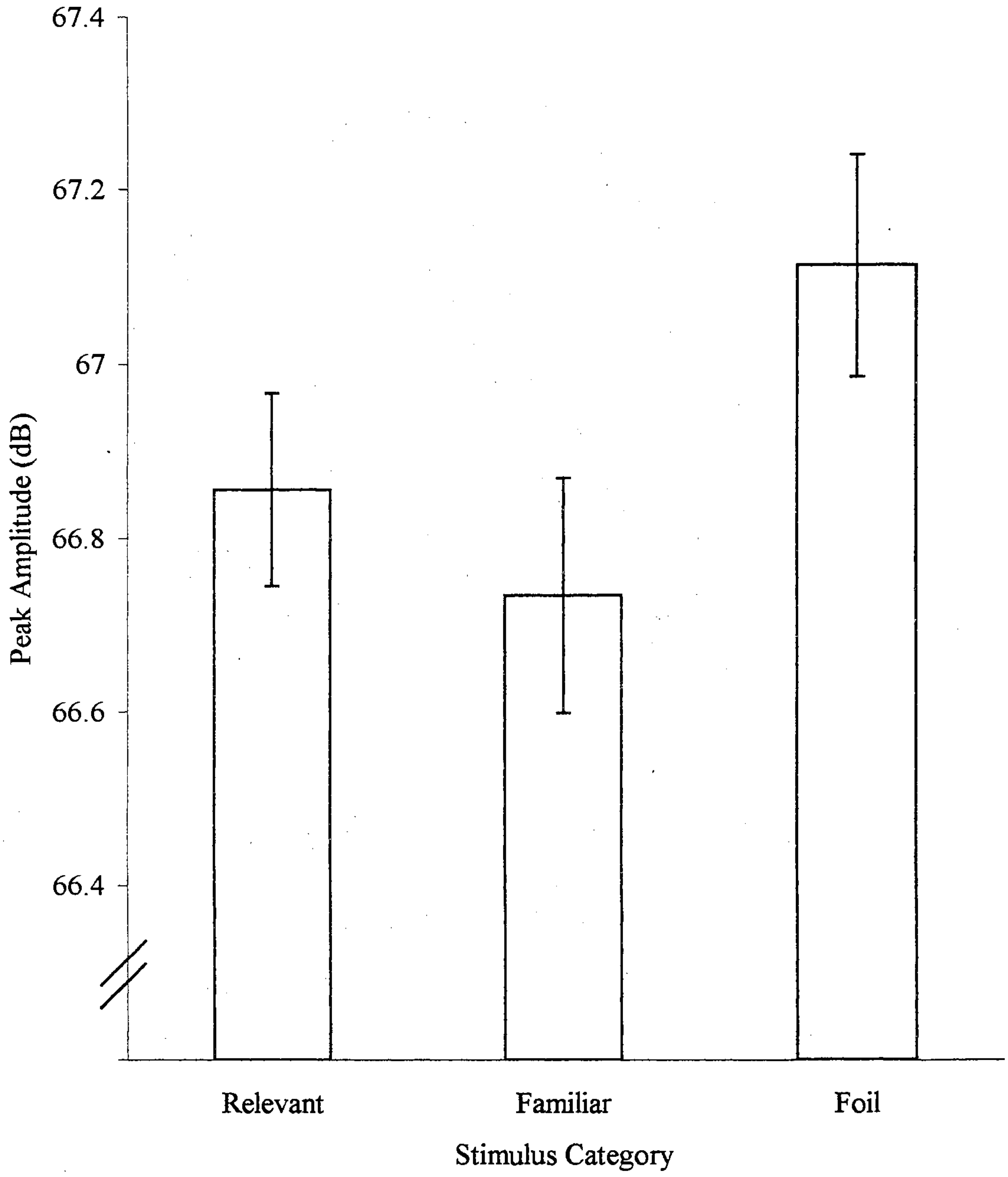


Figure 15. Main effect of stimulus for sagittal PA beta data. Error bars represent one standard error of the mean.

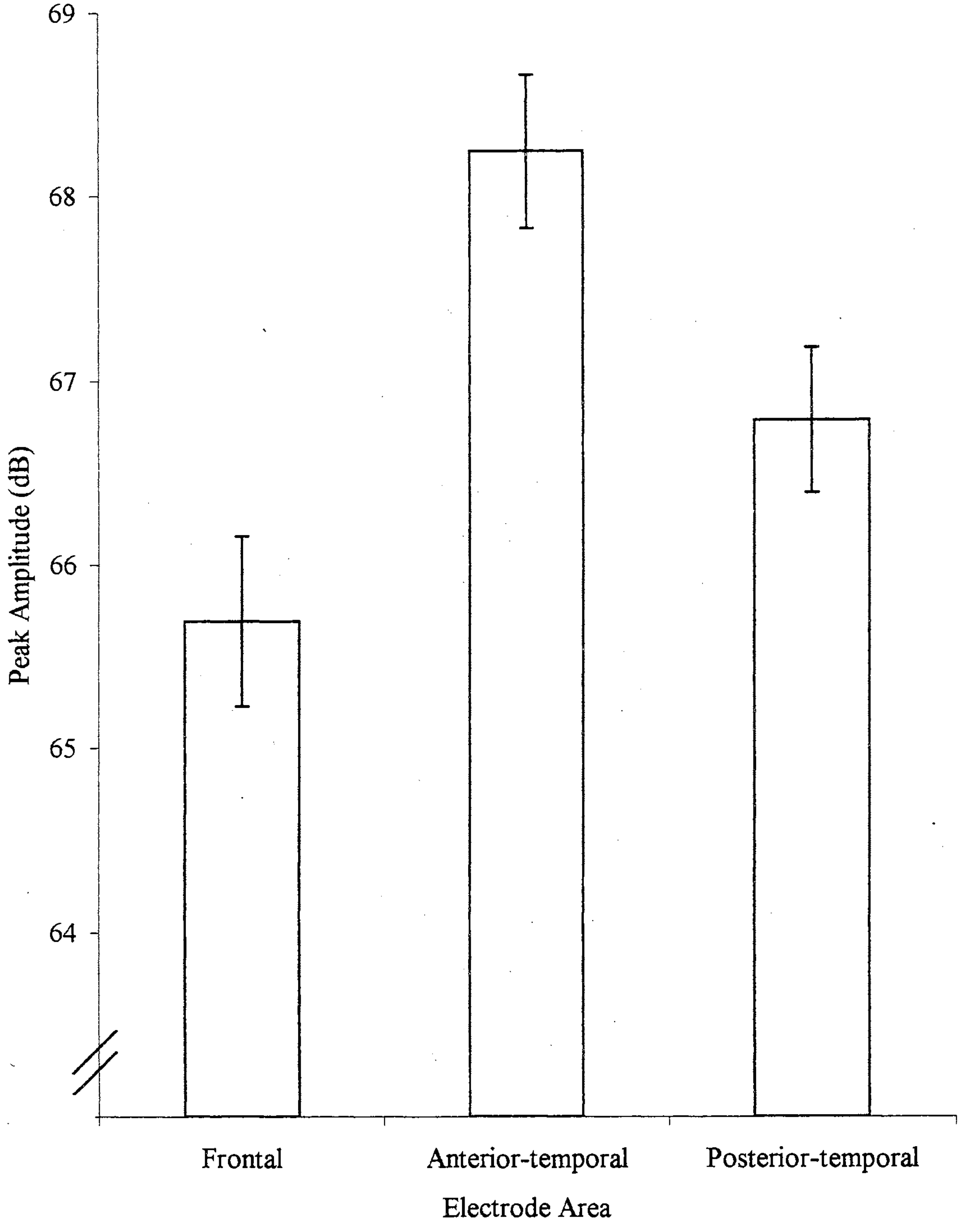


Figure 16. Main effect of electrode for sagittal PA beta data. Error bars represent one standard error of the mean.

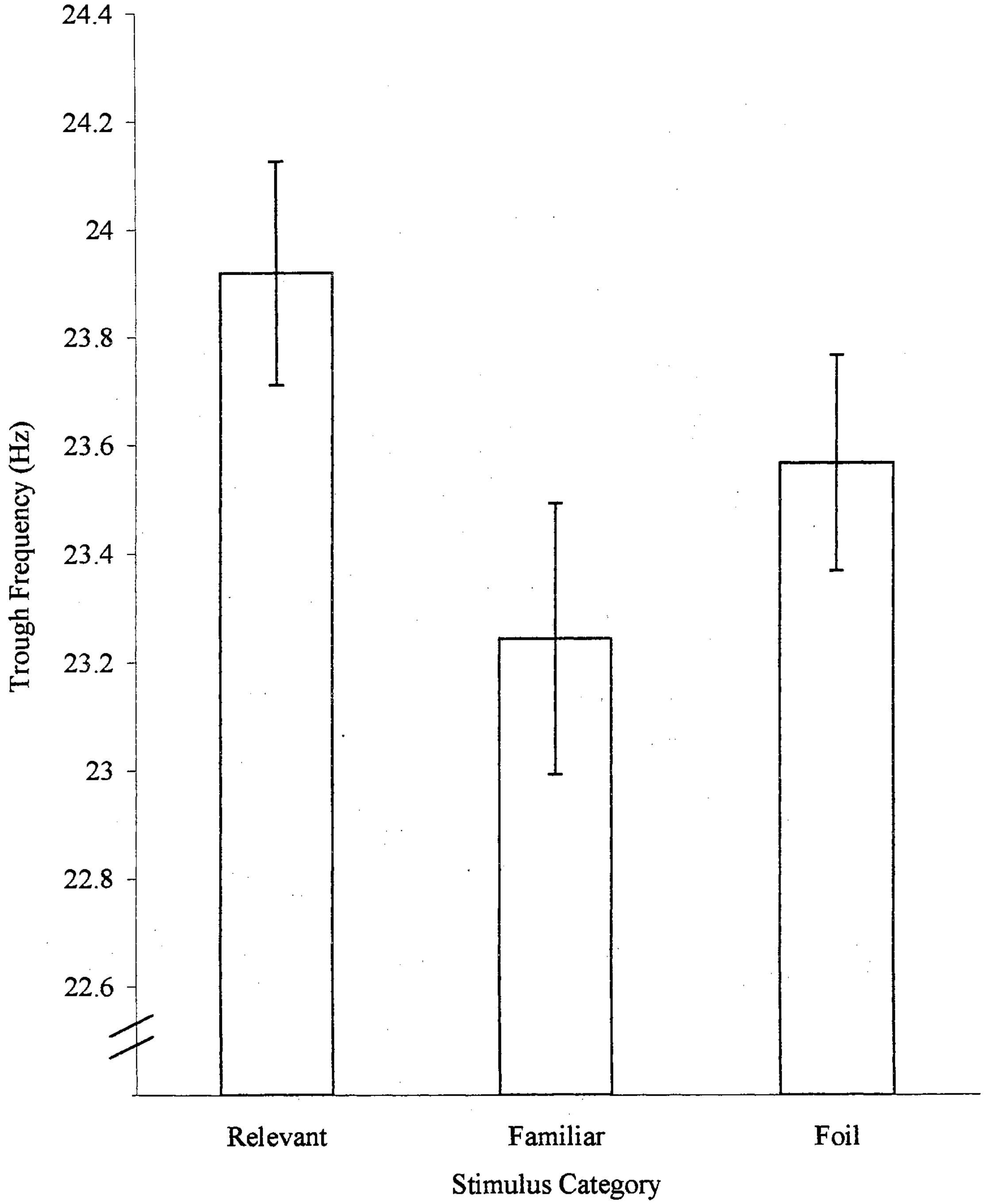


Figure 17. Main effect of stimulus for sagittal TF beta data. Error bars represent one standard error of the mean.

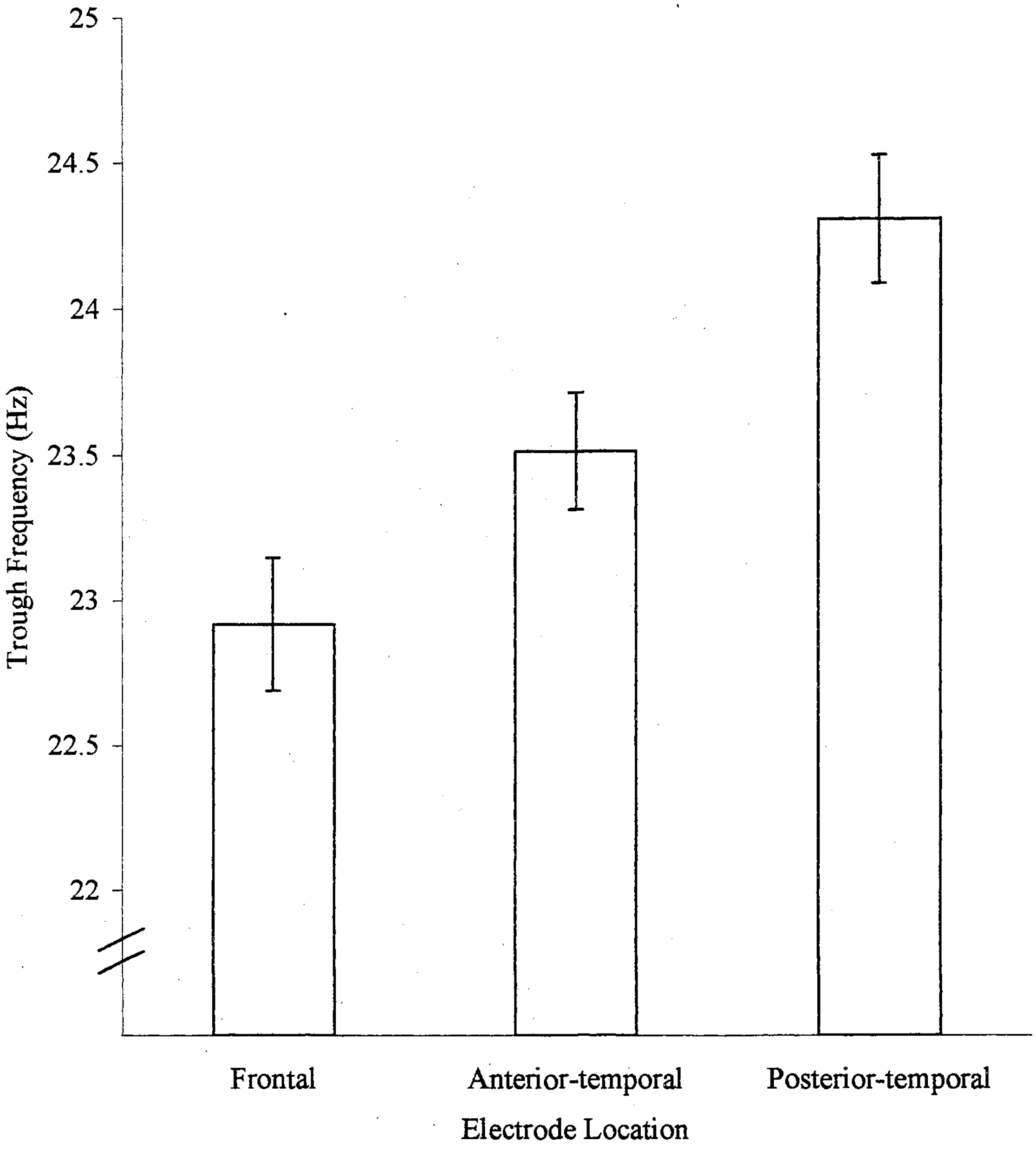


Figure 18. Main effect of electrode for sagittal TF beta data. Error bars represent one standard error of the mean.

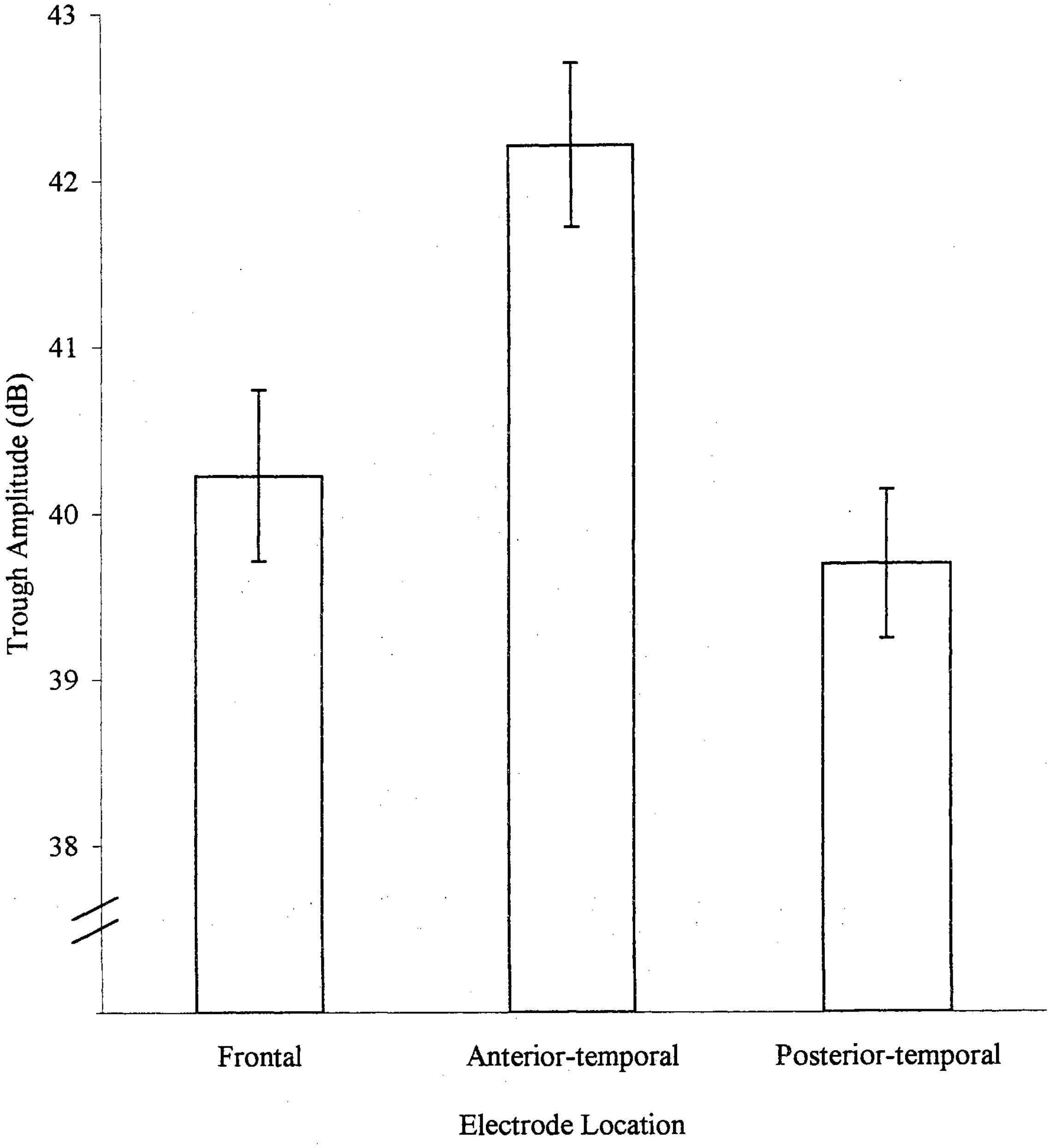


Figure 19. Main effect of electrode for sagittal TA beta data. Error bars represent one standard error of the mean.

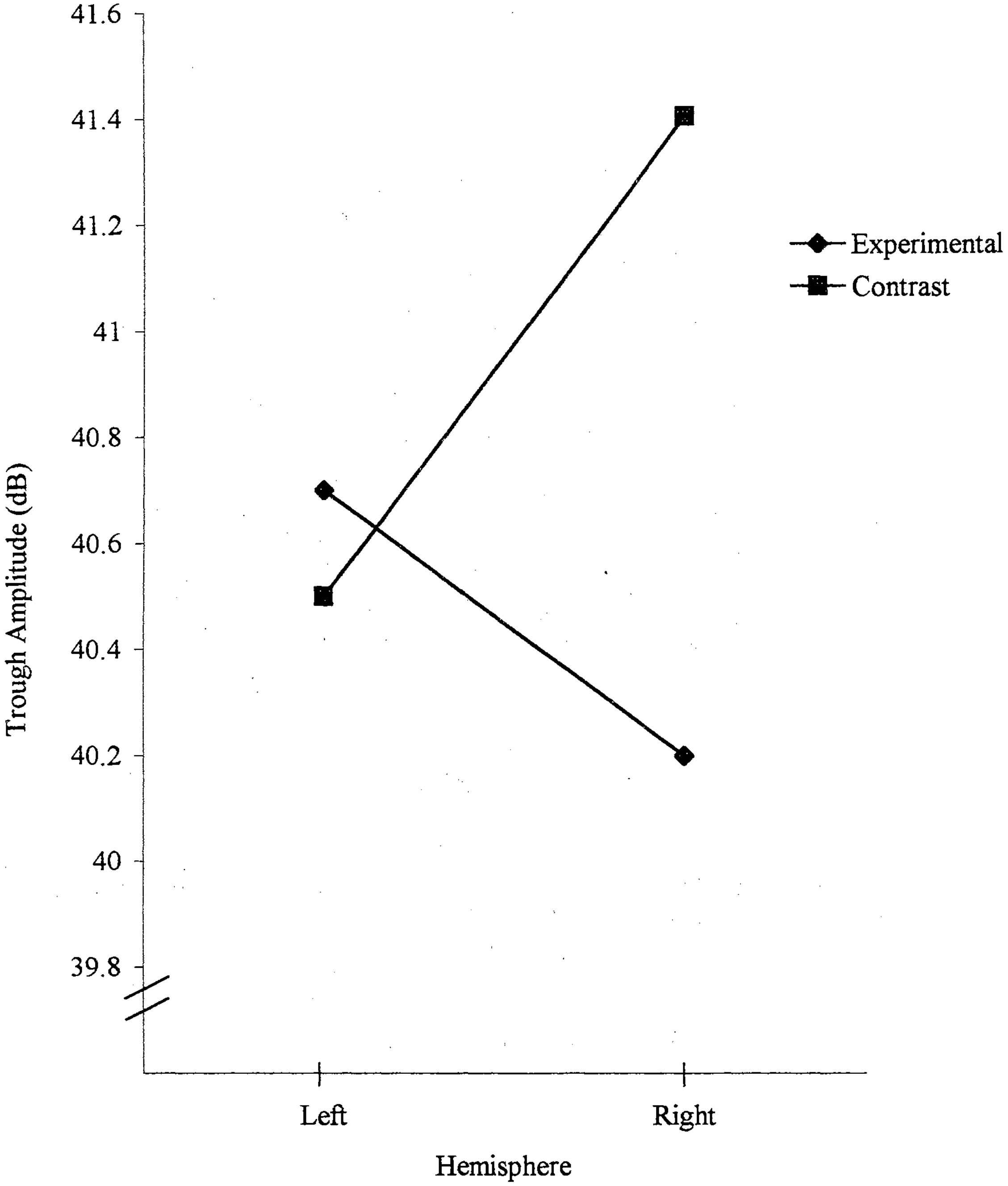


Figure 20. Effect of group by hemisphere for sagittal TA beta data.

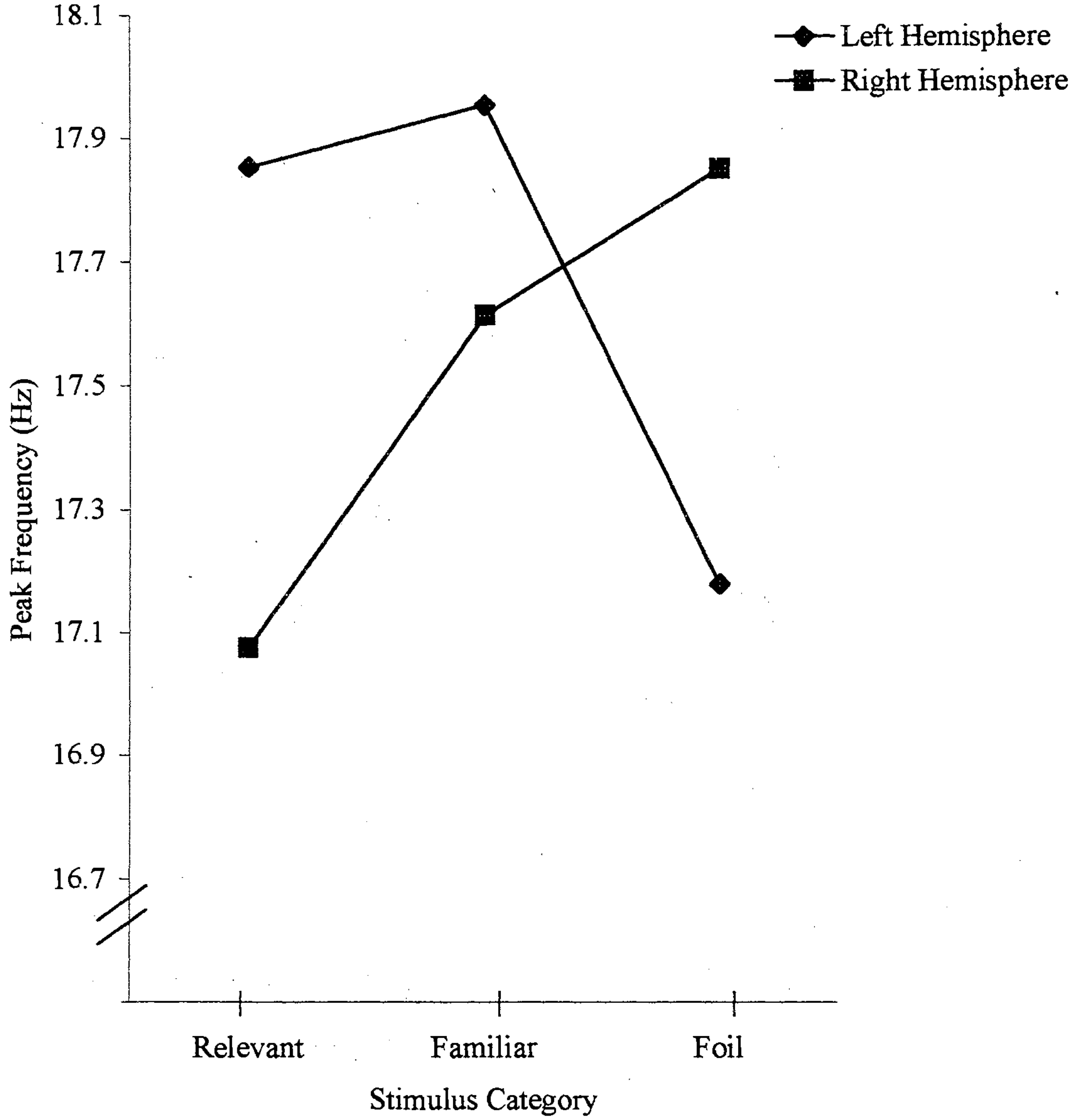


Figure 21. Effect of stimulus by hemisphere for mid-sagittal PF beta data.

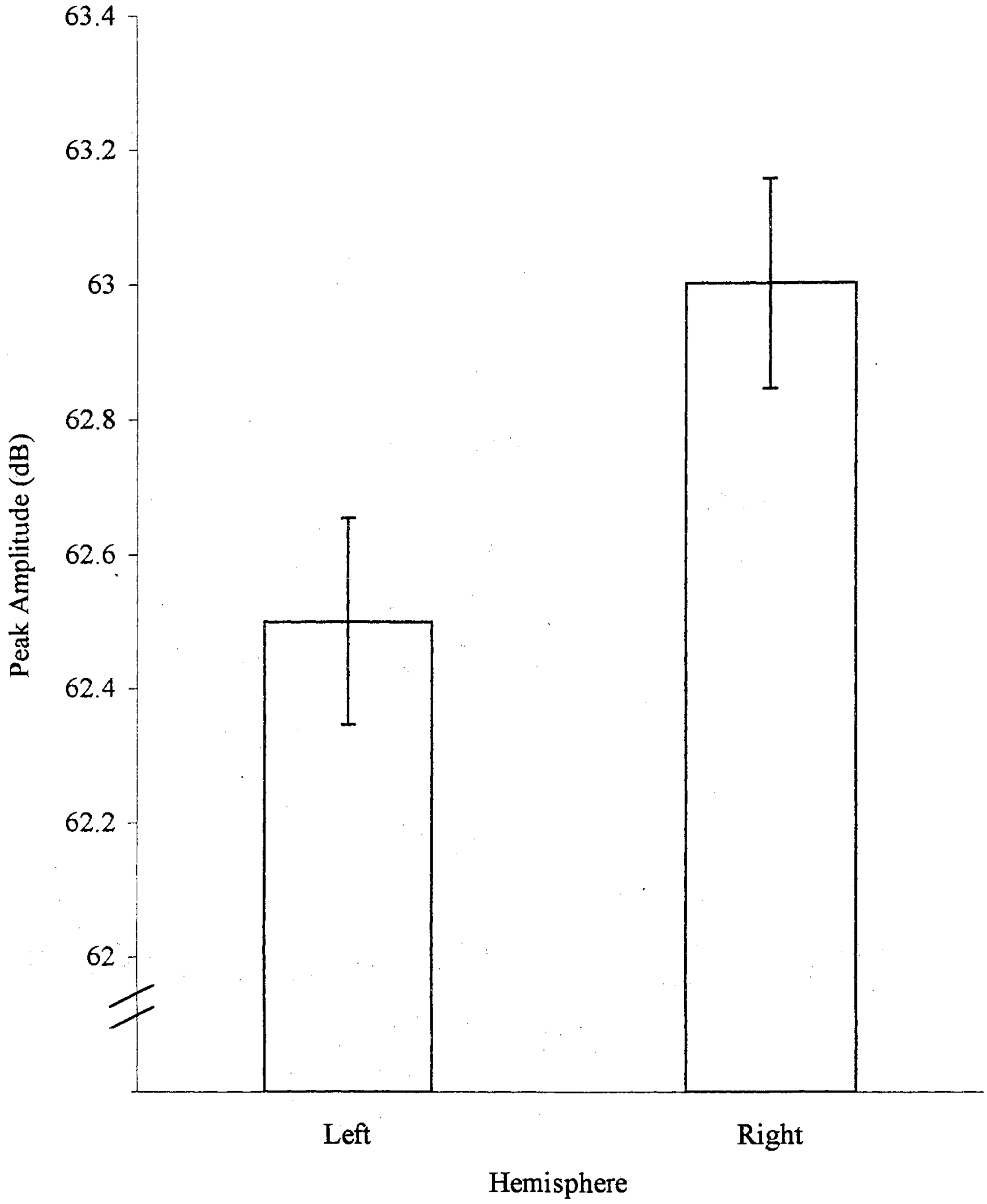


Figure 22. Main effect of hemisphere for mid-sagittal PA beta data. Error bars represent one standard error of the mean.

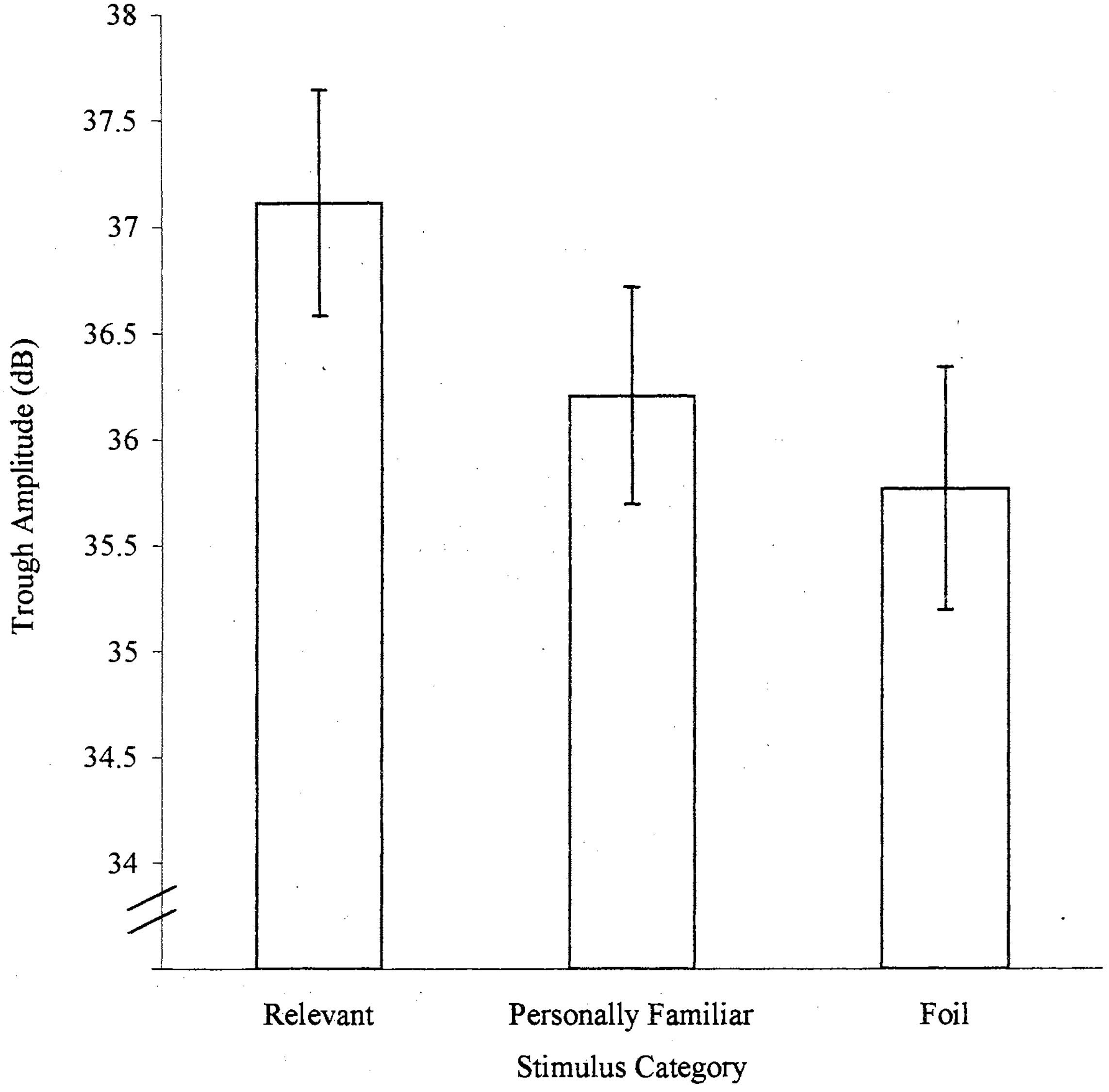


Figure 23. Main effect of stimulus for mid-sagittal TA beta data. Error bars represent one standard error of the mean.

Chapter IV: Discussion

Results of this study revealed that both behavioral and spectral EEG differences between deceptive and non-deceptive participants exist. However, the present results also suggest that many substantive differences exist between the processing of faces and words. Nevertheless, the present findings reveal that both the familiarity of stimuli and deceptive versus nondeceptive processing can be indexed with behavioral and spectral EEG measures.

Behavioral Findings

Based on findings from Lawson and Pratarelli (2000), two hypotheses were tested concerning behavioral measures. Hypothesis one stated that reaction times (RTs) to relevant and foil stimulus categories would differentiate experimental from contrast participants. Similar to Lawson and Pratarelli and in support of hypothesis one, experimental participants responded faster to relevant and foil stimuli than nondeceptive participants, but not to personally familiar stimuli (Figure 4). Hypothesis two stated that response accuracy (RA) to relevant and foil stimuli would differentiate the experimental from contrast group. Also similar to Lawson and Pratarelli, the marginal group by stimulus effect for RA data may indicate that experimental participants are more accurate in responding to foil stimuli (Figure 6). Inconsistent with Lawson and Pratarelli, however, experimental participants in the present study were not more accurate in responding to relevant stimuli than contrast participants.

The lack of a significant group difference found for RA data may be attributable to the use of faces rather than word stimuli used by Lawson and Pratarelli (2000). Participants in Lawson and Pratarelli overall responded correctly to 86.4 percent of words, whereas participants in the present study overall responded correctly to 98.9 percent of faces. These present RA results represent a *ceiling effect* rather than true group differences. The increased accuracy to face stimuli over words may best be explained by the popular metaphor, “pictures are worth a 1000 words” as Pratarelli (1994) has suggested. His study established that pictorial stimuli are more contextually rich than linguistic stimuli, thus allowing individuals to more quickly determine the relevance and familiarity of pictorial referents. Faces can be included as a category of contextually rich images, and therefore, should be expected to command far greater resources during cognitive processing.

In terms of RT and RA measures, previous research has often shown a trade-off between speed and accuracy, (cf., Dickman & Meyer, 1988; Locker & Pratarelli, 1997), such that participants who respond slower tend to be more accurate, and vice-versa, because being more accurate requires more controlled effort. This controlled effort requires more cognitive processing revealed by slower RTs (Kihlstrom, 1987). Locker and Pratarelli (1997) found that deceptive participants responded slower than non-deceptive participants because the act of concealing information to avoid disclosure required more conscious and controlled effort than nonconcealment. Thus, previous research suggests that increased cognitive processing can be indexed by longer RTs. Consistent with Lawson and Pratarelli (2000), however, the present findings do not indicate that increased cognitive processing (i.e. concealing information in comparison to responding truthfully) is reflected by longer RTs (Figure 4). Lawson and Pratarelli (2000) suggested that this departure from previous findings may be due in part to (a) motivation and (b) to subtle differences in task demands.

Lawson and Pratarelli (2000) suggested that deceptive participants may respond faster to stimuli because of differences in motivation. This argument is predicated on the notion that deceiving with impunity is intrinsically enjoyable. They based this argument on observations during participant debriefings that suggested experimental participants enjoyed the challenge of deceiving their examiner. The present study examined this explanation by using a self-report measure of intrinsic and extrinsic motivation. Based on the nonsignificant group findings on this measure, differences in motivation can not account for the present group effects.

The second potential explanation provided by Lawson and Pratarelli (2000) to account for deceptive participants responding faster and more accurately to stimuli implicates task demands. Locker and Pratarelli (1997) had reported that when participants self-selected into the deception group, they believed they were fooling the investigator, and their integrity would be questioned if this were disclosed, i.e., if it was discovered they had taken, from a confederate, a list of words to be presented on the next day's test. Thus, participants assumed that real-life emotional consequences would result if caught. In the present study, however, the potential for deceptive participants to assume any emotional consequences if caught is significantly diminished because (a) participants worked in partnership with their trainer to fool the examiner, and (b) there was no potential loss of integrity if their deception was discovered because they were told to do so in the context of the experiment. That is, the deception had been, in effect, legitimized and operationalized in the task demands. Thus, Locker and Pratarelli's participants would have had to slow down to increase their accuracy in order to maintain their deception while the present participants could afford to speed up.

The notion that task demands may account for group differences was investigated in the present study by examining spectral EEG in the alpha bandwidth. Activity in the alpha bandwidth diminishes under increased attentional and task demands (Klimesch, 1999). The group by stimulus by alpha level interaction for midline alpha ERD data suggests that increased task demands for deceptive participants are consistent with group RT differences to relevant and foil faces (Figure 9). Because including alpha level in this group interaction indicated that lower and upper alpha are indexing distinct processes, future research should directly address the effects of task demands on behavioral indices of deception.

The finding that group RT differences occurred for all stimulus categories except personally familiar faces may be explained procedurally because personally familiar faces were gathered from each participant's prior experiences independent of the experiment while the other stimulus categories were not. Thus, personally familiar faces may be distinct from relevant and foil faces with respect to familiarity. It is well established that familiar stimuli are recognized faster and more accurately than unfamiliar stimuli (Ashcraft, 1994; Moore & Valentine, 1998). Specific to face identification, Moore and Valentine (1998) found that famous faces participants rated as highly familiar were reflected by lower RTs and higher RAs than famous faces participants rated as less familiar. Researchers have attributed this *familiarity effect* to the strength of the memory trace (Ashcraft, 1994). This increased strength for highly familiar faces is presumed to reflect more efficient cortical organization and larger networks with other memories than less familiar faces.

In the present experiment, personally familiar faces were of nationally and internationally known individuals. Thus, these faces were likely to be known to participants for much of their lives. This increase in familiarity and age of exposure may have allowed participants to more quickly recognize personally familiar faces, whereas, the less familiar (i.e., relevants) and unknown (i.e., foils) faces would require longer RTs to accurately assess familiarity. In turn, this increased processing for relevant and foil faces may be viewed in terms of increased task demands. Thus, task demands in relation to face recognition, may not only account for differences between groups in relation to relevant and foil stimuli, but may also account for the lack of group differences for personally familiar faces.

The main effect of stimulus category for RT data corresponds to the familiarity of stimuli in that across groups, participants responded quicker to relevant and familiar faces than foils (Figure 3). However, the main effect of stimulus category for RA data only indicated that across groups, responses to relevant faces were more accurate than foils (Figure 5). Moreover, Lawson and Pratarelli (2000) did not find any main effects of stimulus for RT or RA measures. Thus, it remains unclear as to why, in the present case, participants overall differed in RT and RA.

Self-Report Findings

Based on findings from Lawson and Pratarelli (2000), hypothesis three stated that no significant group differences would be found in relation to intrinsic motivation. This hypothesis was confirmed. Although no group differences in motivation were found, the main effect of motivation (Figure 7) confirms previous findings that intrinsic and extrinsic motivation are distinct processes (Amabile et al., 1994). Intrinsic items indexed participants' interest, emotional engagement, and personal satisfaction during participation in the experiment, whereas extrinsic items indexed participants' perceptions of external rewards and social incentives while participating in the experiment. The main effect of motivation also indicates that participants responded more favorably (i.e., higher Likert ratings) to intrinsic items than extrinsic items. Thus, participants appear to have found the experiment more intrinsically than extrinsically satisfying. Participants' increased focus on intrinsic motivation over extrinsic motivation may lack ecological validity because outside the laboratory, choosing to deceive is, in part, based on the perceived likeliness of being caught and an appreciation for the negative consequences if discovered. Therefore, future research should examine the potential differences between intrinsic and extrinsic motivation of individuals who deceive in real-life events as compared to mock crimes.

Alpha ERD Findings

Positive ERD values reflect a state of alpha desynchronization (e.g., increased attention and task demands) during the test interval while negative ERD values reflect a state of alpha synchronization (e.g., relaxation) during the test interval. Moreover, upper alpha has been found to desynchronize during semantic processing (Klimesch, 1996). Pooled across participants and within variables, ERD means were all positive, indicating a general increase in attention and task demands when faces were presented. Thus, the present results are in line with previous research and theory.

Hypothesis four stated that differences in alpha amplitude will distinguish between stimulus types in terms of familiar and unfamiliar faces. The marginal interaction of stimulus by electrode appears to reflect higher ERD values for foil faces than for relevant and personally familiar faces at posterior-temporal sites (Figure 11). Thus, this effect may reflect increased attention to unfamiliar faces. However, Burgess and Gruzelier (2000) found increased desynchronization for familiar stimuli in comparison to unfamiliar stimuli. The differences between the present results and findings from Burgess and Gruzelier may reflect methodological differences between the two studies. Familiar faces in Burgess and Gruzelier's study were acquired just prior to recognition trials whereas the present experiment utilized a delay of approximately 24 hours between memory acquisition and recognition. In light of the present marginal interaction and differences between the present results and findings from Burgess and Gruzelier, support for hypothesis four is inconclusive.

Hypothesis five stated that a significant interaction between group and stimulus type would be found in relation to alpha amplitude. This would index the increased attentional demands required for deceptive responses over truthful responses. The finding that deceptive participants were indexed by increased ERD in the upper alpha band for relevant stimuli supports this hypothesis (Figure 9). Although numerous studies have clarified that both lower and upper alpha index attentional and task demands, the current group effect may also suggest that group differences in relation to semantic processing of relevant faces exist. Specifically, deceptive participants were assumed to have attached meaning to relevant faces beyond their familiarity in order to selectively respond deceptively to them and not to personally familiar faces.

Deceptive participants were also distinguishable from contrast participants because they had higher ERD values for foil stimuli at lower alpha frequencies (Figure 9). Reflecting on the group by stimulus interaction for RT data, the present group differences for relevant and foil stimuli may correspond to familiarity effects. Alpha EEG may not be sensitive to group differences for personally familiar faces because all participants processed these faces more efficiently (i.e., personally familiar faces have a stronger memory trace) than relevant and foil faces.

Several significant effects involving electrode location were found with respect to alpha ERD data (Figures 8, 10, & 11). These findings illustrate spatial differences in cortical processing. Unfortunately, differences between electrodes are difficult to interpret in that a major limitation of using EEG is its relatively poor spatial resolution. Pfurtscheller, Neuper, and Berger (1994) estimated that cortical activity at a single point blurs from four to five centimeters over the scalp. Due to this poor spatial resolution, main effects of electrode can, at best, be localized to the nearest lobe (Burgess & Gruzelier, 1997). The interaction of electrode by alpha for ERD midline data indicates that lower alpha is more desynchronized in the parietal lobes than upper alpha, whereas upper alpha is more synchronized at the occipital lobes than lower alpha (Figure 8). Also, the main effect of electrode for sagittal ERD data found that alpha was most desynchronized at the posterior-temporal sites (Figure 10). These effects correspond to established findings that posterior regions of the scalp are most sensitive to alpha activity (Empson, 1986; Klimesch, 1999).

Although no formal hypotheses were proposed in terms of hemispheric differences for ERD data, hemispheric differences were expected in light of the established findings of the right hemisphere's superiority in face recognition (Burgess & Gruzelier, 1997; Moscovitch et al., 1993; Schweinberger & Sommer, 1991). The alpha type by hemisphere interaction illustrates that lower alpha is more desynchronized than upper alpha in the right hemisphere (Figure 12). This finding may best be understood by examining hemispheric asymmetries of semantic processing as opposed to face recognition.

Similar to previous studies that have found a right hemisphere superiority for face recognition, Kapur, Friston, Young, Frith, & Frackowiak (1995) found that cortical activation was lateralized to the right hemisphere during a face recognition task. When participants differentiated famous politicians from other famous faces, however, they found that hippocampal regions were activated to a greater extent in the left hemisphere than in the right hemisphere. Thus, the increased activation in the right hemisphere was found for memory processes involving faces, but the increased activation in the left hemisphere was found when semantic judgments about faces were made. The present interaction effect corresponds to Kapur and colleagues' findings that the right hemisphere is less involved in semantic processing (indexed by upper alpha) in comparison to processes critical to face recognition (indexed by lower alpha in terms of attentional processes). Although the lack of a significant effect for alpha type in the left hemisphere does not allow for a definitive interpretation of this effect, future research should clarify what attentional and semantic processes are differentiated by alpha activity.

Spectral Beta Findings

Based on findings from Lawson and Pratarelli (2000), hypothesis six stated that the PF in the beta bandwidth should differentiate experimental from contrast groups in terms of anterior versus posterior processing recorded at midline sites irrespective of stimulus type. The present results did not support this hypothesis. However, future studies need to be performed to examine whether any methodological deviation between Lawson and Pratarelli and the present experiment may explain this difference. Nevertheless, the lack of any group finding for midline beta data may illustrate substantive differences between the processing of faces and words. It is expected that cortical areas responsible for the processing of words are spatially dissimilar from the processing of faces. Thus, the lack of any group effects at midline sites may be indicative of spatial differences in the processing of words versus faces. Lawson and Pratarelli also suggested that PA recorded at midline sites may index deception irrespective of stimulus type. The present results are not consistent with that interpretation.

Hypothesis seven, also based on Lawson and Pratarelli (2000), stated that the TF in the beta bandwidth should differentiate experimental from contrast groups irrespective of stimulus type in terms of anterior versus posterior processing recorded at sagittal electrode sites. Similar to hypothesis six, the present results do not support this interpretation in that TF sagittal data were not sensitive to group differences. However, the significant group by hemisphere interaction for TA sagittal data (as indicated in the ANOVA) may have revealed differences between deceptive responding to faces versus words (Figure 20). Deceptive versus nondeceptive processing may be distinguished between hemispheres in relation to face stimuli, whereas deceptive versus nondeceptive processing is distinguished in the anterior-posterior dimension for words. It should be noted, however, that the MANOVA for sagittal beta data did not reveal any group by hemisphere effects. Therefore, this explanation should be left to future research because of the increased likelihood that the group by hemisphere effect is a type-one error.

Based on differences found by Burgess and Gruzelier (1997) for acquisition versus recognition of faces, hypothesis eight stated that measures at beta bandwidths should differentiate stimulus types in terms of familiarity at posterior electrode sites in the right hemisphere. Although not revealed in the MANOVA (Table 6), the subsequent ANOVA for PF data indicated a significant interaction effect between stimulus category and hemisphere (Figure 21). This interaction may have distinguished foil faces from relevant and familiar faces by increased PF measures lateralized to the right hemisphere. However, the lateralization of PF measures for relevant faces and not familiar faces does not correspond to a familiarity interpretation. Therefore, this hypothesis was not supported by the present interaction.

Several main effects of stimulus for beta data demonstrated processing differences between the three face categories. The effect of stimulus for sagittal PA data discriminated familiar from unfamiliar faces (Figure 15). However, the main effect of stimulus for sagittal TF data differentiated relevant from personally familiar faces (Figure 17). Although not revealed in the MANOVA (Table 6), the subsequent ANOVA for mid-sagittal TA data indicated a main effect of stimulus that also can not be explained in terms of familiarity because relevant faces were differentiated from foil faces (Figure 23). Taken together, these main effects of stimulus category are unclear as to which stimulus type are differentiated with beta EEG. Thus, future research should directly address the effects of familiarity on spectral beta measures.

Beta EEG findings indicated that hemispheric asymmetries may exist both in terms of the processing of faces (Figure 22) and deceptive versus nondeceptive processing of face stimuli (Figure 20). However, neither effect was revealed by their corresponding MANOVAs. In light of the increased likelihood that these two hemisphere effects are type-one errors, future research is required to clarify whether these significant effects indicated by ANOVA analyses are real differences.

As previously stated, the poor spatial resolution of EEG allows for only general interpretation of electrode main effects. The main effect of electrode for midline beta data suggests that the PF is more predominant over the occipital lobes than the parietal lobes (Figure 13). However, beta EEG has not typically been found in relation to the occipital lobes (Empson, 1986). Although interpretation of this finding is unclear, it may reflect higher alpha activity in the occipital lobes. This would occur if leakage from the higher alpha band influenced beta measures. Leakage is a problem with spectral analyses in that high power (dB) values from one frequency can inflate the power values at surrounding frequencies (Warner, 1998). Future research should examine the potential for leakage from higher alpha to influence PF beta values. The four significant main effects of electrode corresponding to each of the four dependent measures examined at sagittal sites indicate that beta activity is sensitive to spatial differences in cortical processing (Figures 14, 16, 18, & 19). Due to the lack of similarities between these sagittal effects, however, no specific interpretations as to which cortical structures are indexed by beta measures can be made.

General Discussion

The purpose of this thesis and dissertation was to examine the potential use of behavioral and spectral EEG measures to distinguish between truthful and deceptive participants who were presented faces related and not related to the scenarios they enacted. The present results reveal that both behavioral differences indexed by RT measures and spectral EEG differences indexed by alpha ERD measures distinguish between deceptive and nondeceptive participants. Moreover, the present alpha ERD findings correspond to established findings of hemispheric asymmetries with respect to the processing of faces and alpha activity being most pervasive at the posterior regions of the scalp.

A secondary purpose of this experiment was to expand on Lawson and Pratarelli's (2000) findings that activity indexed by behavioral and spectral EEG in the beta bandwidth distinguish deceptive from nondeceptive participants. One question examined in the present study relating to findings from Lawson and Pratarelli was whether behavioral and beta EEG measures indexed deception from nondeception in a similar manner with face stimuli as found with words.

Findings from the present study suggest that beta EEG indices of deception examined with respect to faces are not similar to EEG indices of deception to words (Lawson & Pratarelli, 2000). Although the group by hemisphere interaction for sagittal TA beta data (revealed only by the ANOVA) is similar to the group effects found in Lawson and Pratarelli in that deceptive participants may be indexed irrespective of stimulus type, the present interaction does not indicate an anterior-posterior relationship between deceptive and nondeceptive participants (Figure 20). Unfortunately, the present results do not clarify why this potential index of deception is different for faces versus words.

Although the present experiment is, in many ways, methodologically similar to Lawson and Pratarelli's initial experiment, at least two distinctions are present. First, Lawson and Pratarelli examined deception in relation to word recognition, while the current study examined deception in relation to face recognition. Although many psychophysiological studies have examined deception in the context of linguistic cues, the present study is the first known psychophysiological examination of deception in relation to facial cues. Therefore, differences in deception attributable to encoding modality (i.e., processing of faces versus the processing of words) are unknown. Changes in encoding modality could influence EEG indices of deception well before the deceptive act is committed. For example, the examination of deception in relation to words versus faces may have direct effects on what types of strategies a participant utilizes to fool the examiner. Moreover, participants may associate a testing session that utilizes linguistic stimuli in terms of polygraph tests, while a testing session that utilizes faces may be associated with eye-witness testimony. Thus, the lack of similar findings in terms of spectral beta measures does not necessarily imply that Lawson and Pratarelli's findings are limited to linguistic stimuli.

The second known methodological departure from Lawson and Pratarelli (2000) is in terms of personally familiar stimuli. In Lawson and Pratarelli, personally familiar words were considered first hand knowledge because they were taken from objects, people, and activities that participants interacted with and performed on a daily basis. In the present study, however, personally familiar faces consisted of famous individuals that participants recognized, liked, and were relatively influential to their lives, but were unlikely to have met personally. Thus, Lawson and Pratarelli utilized personally familiar stimuli that were acquired through first-hand knowledge while the present design did not.

A second question relating to findings from Lawson and Pratarelli (2000) was whether differences between deceptive and nondeceptive participants could be attributed to motivation or task demands. The lack of any group effect for self-report data indicates that deceptive and nondeceptive participants had similar motivation levels. In contrast, the group by alpha type by stimulus interaction for alpha ERD data does suggest that task demands may account for group differences found with behavioral RT measures (Figure 9). If the difference is real, however, the group by hemisphere interaction for sagittal TA beta data can not be interpreted in terms of task demands because of the lack of any group by hemispheric asymmetries found for alpha ERD measures.

In the present study, stimulus categories were known *apriori* to differ in three ways: (a) foils were unfamiliar to all participants, (b) personally familiar and relevant faces were familiar to all participants, and (c) contrast participants responded truthfully to all faces whereas experimental participants responded truthfully to foil and personally familiar faces but concealed their knowledge of relevant faces. Therefore, a direct index of deception in relation to stimulus categories should only indicate group differences for relevant faces because both the mental processes that facilitate deception and the deceptive act itself are assumed to encompass deception. Group differences that differentiated deceptive from nondeceptive processing were found both in relation to RT and alpha ERD measures for relevant and foil faces (Figures 4 & 9). Therefore, the present findings do not indicate that behavioral or spectral EEG measures directly index deception in relation to stimulus categories.

Although the present group differences can be summarized as indirect indices of deception, non-group findings may index familiar (i.e., personally familiar and relevant faces) from unfamiliar (i.e., foil faces) stimuli. Findings that appear to distinguish familiar from unfamiliar stimuli were found for behavioral, alpha ERD, and beta EEG measures (Figures 3, 11, 15, & 21). However, several findings did not index the processing of stimuli in terms of familiarity (Figures 5, 17, 23, & 24). Thus, the present results do not clearly distinguish familiar from unfamiliar faces.

With respect to the established findings on hemisphere asymmetries for face recognition, the present alpha ERD findings are generally consistent with previous research. However, no clear trends for hemispheric asymmetries were found with respect to beta activity. Thus, future research needs to be conducted to gain a better understanding of what processes involved in the processing of faces and their role in discriminating deceptive from nondeceptive participants are indexed by spectral EEG. For instance, a study that presents faces in the left versus right visual field may allow for more specific interpretations as to the left and right hemisphere's role in face recognition as well as their influence on deceptive processing.

Implications & Future Research

Behaviorally, task demands appear to account for the differences between deceptive and nondeceptive participants. Thus, future research should examine the effects of differing task demands on markers of deception. For instance, an experiment examining group differences between participants who (a) utilize a countermeasure while deceiving designed to increase cognitive workload (e.g., counting backward by threes), (b) participants who use a countermeasure while deceiving designed not to increase cognitive workload (e.g., relaxation), and (c) participants who would not use a countermeasure (i.e., controls) may provide valuable insights as to the effects task demands have on behavioral and spectral EEG measures. Moreover, such a study may provide clues as to group differences found in relation to lower versus upper alpha bands.

The present findings show that spectral EEG components discriminate between deceptive and non-deceptive processing. However, the specific processes indexed by spectral EEG are, at present, unknown. Findings by both Lawson and Pratarelli (2000) and the present study suggest that spectral indices of deception are related to the context in which deception occurs (i.e., in the context of words or faces). Future research should more closely examine markers of deception in relation to differing contexts to clarify the reliability of these markers. Specific to the present findings and Lawson and Pratarelli, a future study examining markers of deception in relation to context by having participants deceive to both faces and words may provide clues as to both the validity and applicability of these markers.

Beta indices of deception in Lawson and Pratarelli (2000) indexed deception irrespective of stimulus category. Thus, their findings suggest that beta EEG activity indexes a deceptive state not specific to the deceptive act itself (i.e., deceptive participants only deceived to relevant words). In the present experiment, the group by hemisphere interaction found with beta EEG also suggests that beta activity indexes a deceptive state. With respect to the MANOVA results, however, the validity of this effect needs to be further explored in light of the increased likeliness that this effect being a Type 1 error.

In terms of EEG analyses, this study utilized two methodological techniques to examine spectral EEG components. Spectral activity in the beta bandwidth was examined using a peak-to-peak technique in order to examine the similarities and differences of the present beta EEG findings with those reported by Lawson and Pratarelli (2000). Alternatively, spectral EEG in the alpha bandwidth was examined using the ERD technique which is commonly used with.studies examining alpha (Klimesch, 1999). The peak-to-peak technique has the advantage in terms of estimating the variation of amplitude and frequency spikes within a particular bandwidth. However, peak-to-peak analysis has the disadvantage of ignoring small changes in amplitude that may indicate important changes in cognitive processing. Conversely, the ERD technique has the advantage of only reporting changes that are specific on an event. However, the ERD technique is criticized for its insensitivity to cortical changes that are not directly related to stimuli (e.g, arousal).

Peak-to-peak and ERD techniques are only a few found in the literature used to examine spectral EEG. Other techniques used to examine spectral data include analysis of individual frequency points (e.g., Lawson and Pratarelli, 2000), coherence analysis (e.g., Nielsen & Chenier, 1999), autocorrelation (e.g., Theiler & Rapp, 1996), and wavelet transformation (e.g., Basar, Schurmann, Demiralp, Basar-Eroglu, & Ademoglu, 2001). The issue of what technique allows for the most sensitive examination of spectral EEG while reliably distinguishing between important cortical and cognitive processes is unclear. Future research should examine these techniques more closely to determine which spectral EEG technique is best for detecting differences between deceptive and non-deceptive processing. Moreover, these various techniques should be examined in terms of how reliable they are at indicating deceptive from nondeceptive processing on an individual basis. Such an examination will facilitate our understanding of deception as-well-as the development of reliable tools for the detection of deception.

The most intriguing finding at present is the behavioral and alpha ERD differences found between deceptive and non-deceptive participants that appears to be a function of task demands. These findings are important because they differ from the findings of previous deception research. The psychophysiological detection of deception, in examining deceptive versus nondeceptive sympathetic autonomic nervous system activity, has not found a reliable index of deception (Bashore & Rapp, 1993). Previous research utilizing event-related potentials have the theoretical advantage of measuring deception more accurately because they index the CNS, but have only been able to discriminate between deceptive and nondeceptive participants based on word familiarity or context violation. However, the current findings not only measure CNS activity, but do not seem to be a function of relevance or familiarity (i.e., familiar versus nonfamiliar) of stimuli. Although the familiarity of stimuli has been found to be a reliable indicator of deception, often unavailable details of the act in question are required to utilize this technique (i.e., the GKT vis a vis Farwell & Donchin, 1991; Rosenfeld et al., 1987). However, group differences found for both relevant and foil faces may be a more valid and reliable measure of deceit because these effects occurred in relation to task processing demands.

A major strength of the present design was its increased emphasis on ecological validity over many psychophysiological examinations of deception in the literature. Specifically, the utilization of scenarios related and not related to criminal behavior allowed for the examination of both cognitive processes related to deceptive acts and processes that facilitate individuals to deceive. However, this design may not be considered an entirely, ecologically valid examination of deception because the experimental participants were informed at the beginning of the experiment that no negative consequences would occur if their deceptive behavior was discovered by the examiner.

Another limitation due to the use of separate scenarios is that group differences could potentially be due to differences between the two scenarios as opposed to differences in deception. The present experiment attempted to minimize this limitation by incorporating scenarios that were relatively equal in task difficulty, detail, and length.

Nevertheless, the potential for group differences to have indexed differences attributable to the two scenarios and not to deception exist.

In light of these potentially serious limitations, future research is required to determine the validity and reliability of behavioral and spectral EEG markers of deception. Second, statistical discrimination techniques should be employed to determine whether these markers can differentiate deceptive from nondeceptive participants on an individual basis. Third, future research needs to examine whether this measure is sensitive to a conscious attempt to trick the examiner as in the use of physical and mental countermeasures. These future studies will allow for better assessment of the applicability of behavioral and spectral EEG as markers of deception, thus benefiting society both in terms of traditional lie detection and the validity of eye-witness testimony.

Conclusions

This study has provided electrophysiological as well as behavioral evidence that deceit can be detected using CNS measures of cognitive processing. Also, the evidence suggests that spectral indices of deception that utilize face stimuli share both similarities and differences with indices of deception utilizing words. These findings suggest that spectral EEG can be used to further the understanding of lie detection, the nature of deception, and ultimately guilt.

References

Ackerman, P. T., Dykman, R. A., Oglesby, D. M., & Newton, J. E. (1994). EEG power spectra of children with dyslexia, slow learners, and normally reading children with ADD during verbal processing. Journal of Learning Disabilities, 27, 619-630.

Adrian, E. D. & Matthews, B. H. C. (1934). The Berger rhythm: Potential changes from the occipital lobes of man. Brain, 57, 355.

Allen, J. J., Iacono, W.G. (1997). A comparison of methods for the analysis of event – related potentials in deception detection. Psychophysiology, 34, 234 – 240.

Allen, J. J., Iacono, W. G., & Danielson, K. D. (1992). The identification of concealed memories using event-related potential and implicit behavioral measures: A methodology for prediction in the face of individual differences. Psychophysiology, 29, 504-522.

Amabile, T. M., Hill, K. G., Hennessey, B. A., & Tighe, E. M. (1994). The Work Preference Inventory: Assessing intrinsic and extrinsic motivational orientations. Journal of Personality and Social Psychology, 66, 950 - 967.

Andreassi, J. L. (1989). Psychophysiology: Human behavior and physiological response. Hillsdale, NJ: Erlbaum.

Ashcraft, M. H. (1994). Human memory and cognition (2nd ed). New York: HarperCollins.

Basar, E., Basar – Eroglu, C., Karakas, S., & Schurmann, M. (2000). Brain oscillations in perception and memory. International Journal of Psychophysiology, 35, 95 – 124.

Basar, E., Rosen, B., Basar – Eroglu, C., & Greitschus, F. (1987). The associations between 40 – Hz EEG and the middle latency response of the auditory evoked potential. International Journal of Neuroscience, 33, 103 – 117.

Basar, E., Schurmann, M., Demiralp, T., Basar-Eroglu, C., & Ademoglu, A. (2001). Event-related oscillations are 'real brain responses' – wavelet analysis and new strategies. International Journal of Psychophysiology, 39, 91 – 127.

Basar-Eroglu, C., Basar. E., Demilrap, T., & Schurmann, M. (1992). P300-response: Possible psychophysiological correlates in delta and theta frequency channels. A review. International Journal of Psychophysiology, 13, 161 – 179.

Bashore, T. R. & Rapp, P. E. (1993). Are there alternatives to traditional polygraph procedures? Psychological Bulletin, 113, 3-22.

Boaz, T. L., Perry, N. W., Raney, G., Fischler, I. S., & Shuman, D. (1991). Detection of guilty knowledge with event-related potentials. Journal of Applied Psychology, 76, 788-795.

Bradley, M. T. & Janisse, M. P. (1981). Accuracy demonstrations, threat, and the detection of deception: Cardiovasular, electrodermal, and pupillary measures. Psychophysiology, 18, 307-315.

Burgess, A. P. & Gruzelier, J. H. (1997). Localization of word and face recognition memory using topographical EEG. Psychophysiology, 34, 7 – 16.

Burgess, A. P. & Gruzelier, J. H. (2000). Short duration power changes in the EEG during recognition memory for words and faces. Psychophysiology, 37, 596 - 606.

Clendening, L. (1931). The history of certain medical instruments. Annals of International Medicine, 4, 176 - 189.

Cohen, J. (1977). Statistical power analysis for the behavioral sciences. London, England: Academic Press.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671 - 684.

Davidson, R. J., Jackson, D., & Larson, C. L. (2000). Human electroencephalography. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), Handbook of Psychophysiology (pp. 27 - 52). Cambridge, UK: Cambridge University Press.

Dickman, S. J. & Meyer, D. E. (1988). Impulsivity and speed-accuracy tradeoffs in information processing. Journal of Personality & Social Psychology, 54, 274 - 290.

Donchin, E. & Coles, M. G. (1988). Is the P300 component a manifestation of context updating? Behavioral and Brain Sciences, 11, 357 – 427.

Doppelmayr, M., Klimesch, W., Pachinger, T., & Ripper, B. (1998). Individual differences in brain dynamics: Important implications for the calculation of event – related band power measures, Biological Cybernetics, 79, 49 – 57.

Duncan – Johnson, C. C. & Donchin, E. (1977). On quantifying surprise: The variation of event – related potentials with subjective probability. Psychophysiology, 14, 456 – 467.

Eckhorn, R., Bauer, R., Jordan, W., Brosch, M., Kruse, W., Munk, M. & Reitboeck, H. J. (1988). Coherent oscillations: A mechanism of feature linking in the visual cortex? Multiple electrode and correlation analyses in the cat. Biological Cybernetics, 60, 121 – 130.

Elaad, E. (1994). The accuracy of human decisions and objective measurements in psychophysiological detection of knowledge. The Journal of Psychology, 128, 267-280.

Elaad, E., Ginton, A., & Jungman, N. (1992). Detection measures in real-life criminal guilty knowledge tests. Journal of Applied Psychology, 77, 757-767.

Empson, J. (1986). Human brainwaves: The psychological significance of the electroencephalogram. New York: Stockton Press.

Farwell, L. A. & Donchin, E. (1991). The truth will out: Interrogative polygraphy ("lie detection") with event-related potentials. Psychophysiology, 28, 531-547.

Fischler, I., Childers, D. G., Achariyapaopan, T., & Perry, N. W. (1985). Brain potentials during sentence verification: Automatic aspects of comprehension. Biological Psychology, 21, 83 – 105.

Ford, C. V. (1995). Lies lies lies: The psychology of deceit. Washington DC: American Psychiatric.

Gevins, A., Smith, M. E., McEvoy, L., & Yu, D. (1997). High – resolution EEG mapping of cortical activation related to working memory: Effects of task difficulty, type of processsing, and practice. Cerebral Cortex, 7, 374 – 385.

Gratton, G. (2000). Biosignal Processing. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), Handbook of Psychophysiology (pp. 900 - 923). Cambridge, UK: Cambridge University Press.

Gur, R. C., Ragland, J. D., Mozley, L. H., Mozley, P. D., Smith, R., Alavi, A., Bilker, W., & Gur, R. E. (1997). Lateralized changes in regional cerebral blood flow during performance of verbal and facial recognition tasks: correlations with performance and effort. Brain and Cognition, 33, 388 – 414.

Harmony, T., Fernandez, T., Silva, J., Bernal, J., Diaz-Comas, L., Reyes, A., Marosi, E., Rodriguez, M., & Rodriguez, M. (1996). EEG delta activity: An indicator of attention to internal processing during performance of mental tasks. International Journal of Psychophysiology, 24, 161 – 171.

Haxby, J. V., Ungerleider, L. G., Horwitz, B., Maisog, J. M., Rapoport, S. I., & Grady, C. L. (1996). Face encoding and recognition in the human brain. Proceedings of the National Acadamy of Science. USA, 93, 922 – 927.

Honts, C. R. (1994). Psychophysiological detection of deception. Current Directions in Psychological Science, 3, 77 – 82.

Honts, C. R. & Raskin, D.C. (1988). A field study of the validity of the directed lie control question. Journal of Police Science and Administration, 16, 56-61.

Horne, J. A., & Minard, A. (1985). Sleep and sleepiness following a behaviourally "active" day. Ergonomics, 28, 567 – 575.

Inbau, F. E. (1942). Lie detection and criminal interrogation. Baltimore: Williams & Wilkins.

Johnson, R. (1986). A triarchic model of P300 amplitude. Psychophysiology, 23, 367 – 384.

Kapur, N., Friston, K. J., Young, A., Frith, C. D., & Frackowiak, R. S. J. (1995). Activation of human hippocampal formation during memory for faces: A PET study. Cortex, 31, 99 – 108.

Kelso, J. A. S. (1999). Dynamic patterns: The self – organization of brain and behavior. Cambridge, MA: MIT Press.

Keppel, G. (1991). Design and analysis: A researcher's handbook (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Kihlstrom, J. F. (1987). The cognitive unconscious. Science, 237, 1445 – 1452.

Kleinmuntz, B. & Szucko, J. J. (1982). On the fallibility of lie detection. Law & Society Review, 17, 85-103.

Kleinmuntz, B. & Szucko, J. J. (1984). Lie detection in ancient and modern times: A call for contemporary scientific study. American Psychologist, 39, 766 - 776.

Klimesch, W. (1996). Memory processes, brain oscillations and EEG synchronization. International Journal of Psychophysiology, 24, 61 – 100.

Klimesch, W. (1997). EEG – alpha rhythms and memory processes. International Journal of Psychophysiology, 26, 319 – 340.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. Brain Research Reviews, 29, 169 – 195.

Klimesch, W., Doppelmayr, M., Pachinger, T., & Ripper, B. (1997). Brain oscillations and human memory: EEG correlates in the upper alpha and theta band. Neuroscience Letters, 238, 9 – 12.

Klimesch, W., Doppelmayr, M., Pachinger, T., & Russegger, H. (1997). Event – related desynchronization in the alpha band and the processing of semantic information. Cognitive Brain Research, 6, 83 – 94.

Klimesch, W., Schimke, H., Doppelmayr, M., Ripper, B., Schwaiger, J., & Pfurtscheller, G. (1996). Event – related desynchronization (ERD) and the Dm effect:

Does alpha desynchronization during encoding predict later recall performance? International Journal of Psychophysiology, 24, 47 – 60.

Kolb, B., Milner, B., & Taylor, L. (1983). Perception of faces by patients with localized cortical excisions. Canadian Journal of Psychology, 37, 8 – 18.

Krause, C. M., Sillanmaki, L., Koivisto, M., Saarela, C., Haggqvist, A., Laine, M., & Hamalainen, H. (2000). The effects of memory load on event-related EEG desynchronization and synchronization. Clinical Neurophysiology, 111, 2071 - 2078.

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

Larson, J. A. (1932). Lying and its detection. Chicago: University of Chicago Press.

Lawson, A. L., & Pratarelli, M. E. (2000). Recognition of concealed information with behavioral and spectral analyses. (Report No. DoDPI-P-0017). Fort Jackson, SC: Department of Defense Polygraph Institute.

Lea, H. C. (1973). Superstition and force. In E. Peter & A. E. Howland (Ed. and Trans.), The ordeal. Philadelphia: University of Pennsylvania Press. (Original work published 1866)

Lee, C. D. (1953). The instrumental detection of deception: The lie test. Springfield, Illinois: Charles C. Thomas.

Locker, L., Jr. & Pratarelli, M. E. (1997). Lexical decision and the detection of concealed information. The Journal of Credibility Assessment and Witness Psychology, 1, 33 - 43.

Lopes da Silva, F. H. (1992). The rhythmic slow activity (theta) of the limbic cortex: An oscillation in search of a function. In E. Basar & T. H. Bullock (Eds.), Induced Rhythms in the Brain. Birkhauser, Boston, pp. 83 – 102.

Loring, D. W. & Sheer, D. E. (1984). Laterality of 40 Hz EEG and EMG during cognitive performance. Psychophysiology, 21, 34 – 38.

Lough, E. & Kiesow, F. (1896). Fear. (5th ed.). London, England: Longmans, Green, & Co..

Lykken, D. T. (1959). The GSR in the detection of guilty knowledge. Journal of Applied Psychology, 43, 385-388.

Lykken, D. T. (1979). Psychology and the lie detector industry. American Psychologist, 29, 725 - 739.

Lykken. D. T. (1998). A tremor in the blood: Uses and abuses of the lie detector (2nd ed.). New York: Plenum Trade.

Marston, W. M. (1917). Systolic blood pressure symptoms of deception. Journal of Experimental Psychology, 2, 117-163.

Marston, W. M. (1938). The lie detector test. New York: Richard R. Smith.

Moore, V. & Valentine, T. (1998). The effect of age of acquisition on speed and accuracy of naming famous faces. The Quarterly Journal of Experimental Psychology, 51, 485 - 513.

Moscovitch, M., Scullion, D., & Christie, D. (1976). Early versus late stages of processing and their relation to functional hemispheric asymmetries in face recognition. Journal of Experimental Psychology: Human Perception and Performance, 2, 401 – 416.

Munsterberg, H. (1908). On the witness stand: Essays on psychology and crime. Garden City, New York: Doubleday, Page, & Company.

Nielsen, T. A. & Chenier, V. (1999). Variations in EEG coherence as an index of the affective content of dreams from REM sleep: Relationships with face imagery. Brain and Cognition, 41, 200 - 212

Neisser, U. (1967). Cognitive Psychology. New York: Appleton-Century-Crofts.

Perrett, D. I., Hietanen, J. K., Oram, M. W., & Benson, P. J. (1992). Organization and functions of cells responsive to faces in the temporal cortex. Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences, 335(1273), 23 – 30.

Perrin, F., Pernier, J., Bertrand, O., Giard, M. H., & Echallier, J. F. (1987). Mapping of scalp potentials by surface spline interpolation. Electroencephalography and Clinical Neurophysiology, 66, 75 - 81.

Pfurtscheller, G., Neuper, C., & Berger, J. (1994). Source localization using event-related desynchronization (ERD) within the alpha band. Brain Topography, 6, 269 - 275.

Pratarelli, M. E. (1991). Prosody and semantic activation: A combined electrophysiological and behavioral study. Unpublished doctoral dissertation, University of Southern California, Los Angeles.

Pratarelli, M. E. (1994). Semantic processing of pictures and spoken words: Evidence from event-related brain potentials. Brain and Cognition, 24, 137-157.

Pritchard, W. (1981). The psychophysiology of P300. Psychophysiology of N200/N400: A review and classification scheme. In P. K. Ackles, J. R. Jennings, & M. G.

H. Coles (Eds.), Advances in Psychophysiology (Vol. 4, pp. 43 – 106). Greenwich, CT: JAI Press, Inc.

Rajah, M. N., McIntosh, A. R., & Grady, C. L. (1999). Frontotemporal interactions in face encoding and recognition. Cognitive Brain Research, 8, 259 – 269.

Raskin, D. C. (Ed.). (1989). Psychological methods in criminal investigation and evidence. New York: Springer.

Reeve, J. M. & Cole, S. G. (1987). Integration of affect and cognition in intrinsic motivation. Journal of Criminal Law, Criminology, and Police Science, 37, 542 - 547.

Reid, J. E. (1947). A revised questioning technique in lie detection tests. Journal of Criminal Law, Criminology and Police Science, 37, 542-547.

Rolls, E. T. (1992). Neurophysiological mechanisms underlying face processing within and beyond the temporal cortical visual areas. Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences, 335(1273), 11 – 20.

Rosenfeld, J. P., Angell, A., Johnson, M., & Qian, J. (1991). An ERP – based, control – question lie detector analog: Algorithms for discriminating effects within individuals' average waveforms. Psychophysiology, 28, 319 – 335.

Rosenfeld, J. P., Nasman, V. T., Whalen, R., Cantwell, B., & Mazzeri, L. (1987). Late vertex positivity in event-related potentials as a guilty knowledge indicator: A new method of lie detection. International Journal of Neuroscience, 34, 125-129.

Rugg, M. D. & Coles, M. G. H. (1996). Electrophysiology of Mind: Event – Related Brain Potentials and Cognition. New York: Oxford University Press.

Salansky, N., Fedotchev, A., & Bondar, A., (1995). High-frequency resolution EEG: Results and opportunities. American Journal of EEG Technology, 35, 98-112.

Schweinberger, S. R. & Sommer, W. (1991). Contributions of stimulus encoding and memory search to right hemisphere superiority in face recognition: Behavioural and electrophysiological evidence. Neuropsychologia, 29, 389 – 413.

Sergent, J., Ohta, S., & MacDonald, B. (1992). Functional neuroanatomy of face and object processing: A positron emission tomography study. Brain, 115, 15 – 36.

Sergent, J. & Signoret, J. (1992). Functional and anatomical decomposition of face processing: Evidence from prosopagnosia and PET study of normal subjects. Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences, 335(1273), 55 – 61.

Shaw, J. C. (1996). Intention as a component of the alpha-rhythm response to mental activity. International Journal of Psychophysiology, 24, 7 – 23.

Sheer, D. E. (1984). Focused arousal, 40 – Hz EEG, and dysfunction. In Th. Elbert, B. Rockstroh, W. Lutzenberger, & N. Birbaumer (Eds.), Self – Regulation of the Brain and Behavior. NewYork: Springer – Verlag.

Silva, A., Leong, G. B., & Wine, D. B. (1993). Misidentification delusions, facial misrecognition, and right brain injury. The Canadian Journal of Psychiatry, 38, 239 – 241.

Spydell, J. D., Ford, M. R., & Sheer, D. E. (1979). Task dependent cerebral lateralization of the 40 hertz EEG rhythm. Psychophysiology, 16, 347 – 350.

Stelmack, R. M., Houlihan, M., & Doucet, C. (1996). Event-related potentials and the detection of deception: A two-stimulus paradigm. Department of Defence Polygraph Institute, Report No. DoDPI93-R-0004.

Summers W. G. (1936). Guilt distinguished from complicity. Psychological Bulletin, 33, 787.

Tallon-Baudry, C., Kreiter, A., & Bertrand, O. (1999). Sustained and transient oscillatory responses in the gamma and beta bands in a visual short-term memory task in humans. Visual Neuroscience, 16, 449 – 459.

Theiler, J. & Rapp, P. E. (1996). Re-examination of the evidence for low-dimensional, nonlinear structure in the human electroencephalogram. Electroencephalography and Clinical Neurophysiology, 98, 213 – 222.

Tiitinen, H., Sinkkonen, J., Reinikainen, K., Alho, K., Lavikainen, J., & Naatanen, R. (1993). Selective attention enhances the auditory 40 – Hz transient response in humans. Nature, 364, 59 – 60.

Trovillo, P. V. (1939). A history of lie detection. Journal of Criminal Law, Criminology, and Police Science, 30, 848 – 881.

Tulving, E., Kapur, S., Craik, F. I. M., Moscovitch, M. & Houle, S. (1994). Hemispheric encoding/retrieval asymmetry in episodic memory: Positron emission tomography. Procedings from the National Acadamy of Science. USA, 91, 2016 – 2020.

Ungerleider, L. G. & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. H. Goodale, & R. J. W. Mansfield (Eds.), The Analysis of Visual Behavior. Cambridge, MA: MIT Press.

Warner, R. M. (1998). Spectral analysis of time-series data. New York: Guilford Press.

Watanabe, S., Kakigi, R., Koyama, S., & Kirino, E. (1999). Human face perception traced by magneto - and electro – encephalography. Cognitive Brain Research, 8, 125 – 142.

Weiss, S. & Rappelsberger, P. (1996). EEG coherence within the 13 – 18 Hz band as a correlate of a distinct lexical organisation of concrete and abstract nouns in humans. Neuroscience Letters, 209, 17 – 20.

Weiss, S. & Rappelsberger, P. (2000). Long-range EEG synchronization during word encoding correlates with successful memory performance. Cognitive Brain Research, 9, 299 - 312.

Whiten, A. & Byrne, R. W. (1988). Tactical deception in primates. Behavioral and Brain Sciences, 11, 233 - 273.

Williamson, S. J., Kaufman, L., Curtis, S., Lu, Z. – L., Michel, C. M., & Wang, J. Z. (1996). Neural substrates of working memories are revealed magnetically by the local suppression of alpha rhythm, in: I. Hashimoto, Y. C. Okada, S. Ogawa (Eds.), Visualization of Information Processing in the Human Brain: Recent Advances in MEG and Functional MRI, EEG suppl, 47 (pp. 163 – 180). Amsterdam: Elsevier.

Wood, C. C. & Allison, T. (1981). Interpretation of evoked potentials: A neurophysiological perspective. Canadian Journal of Psychology, 35, 113 – 135.

Wong, P. H. K., (1991). Introduction to Brain Topography. NewYork, NY: Plenum Press.

Appendix A

Naming/Preference Task to Gather and Norm Personally Familiar Words

---

You will be shown a face image for a short time and then asked to answer several questions. Answer each of the questions **<u>if you can</u>** by circling the correct answer or filling in the blank.

*

Is this face familiar to you?	**YES NO**
What is the name of this person?	________________________
Rate how much you like this person	
(1 = not at all; 5 = very much):	**1 2 3 4 5**
How influential was this person to your life?	
(1 = not at all; 5 = very much)	**1 2 3 4 5**

* Faces were presented in color.

Appendix B

Experiment Interest Survey

For the following questions, please fill in the blank next to each question corresponding to the following scale: 1 = was never or almost never true of me; 2 = was seldom or sometimes true of me; 3 = was often or usually true of me; 4 = was always or almost always true of me.

1. I am not that concerned about what the trainer thought about my performance. _________
2. I would have preferred more clear goals during the experiment. _________
3. I enjoyed the most difficult tasks of the experiment the most. _________
4. I am keenly aware of the goals I had for doing the experiment well. _________
5. I would have liked the experiment to have provided me with more opportunities for increasing my knowledge and skills. _________
6. To me, success means doing better in the experiment than other people. _________
7. I would have preferred to figure more things out for myself during the experiment. _________
8. No matter what the outcome of the research, I am satisfied that I gained a new experience. _________
9. I enjoyed the relatively simple, straightforward tasks of the experiment the most. _________
10. I was keenly aware of the research goals I had for myself. _________
11. Curiosity was much of the driving force I had for my performance on the experiment. _________
12. I was less concerned with the experiment tasks that I did than what I got for it. _________
13. I enjoyed tackling problems completely new to me that occurred during the experiment. _________

14. I preferred the aspects of the experiment I knew I could do well over the tasks that stretched my abilities. __________

15. I was concerned about how other people were going to react to my ideas during the experiment. __________

16. I seldom thought about my performance during the experiment. __________

17. I was more comfortable with aspects of the experiment where I set my own goals. __________

18. During the experiment, I believed that there was no point in doing a good job if nobody else knew about it. __________

19. I was strongly motivated by the extra-credit I earned during the experiment. __________

20. During the experiment, it was important for me to do what I enjoyed most. __________

21. I preferred doing the experimental tasks with clearly specified procedures. __________

22. As long as I enjoyed participating in the experiment, I was not concerned about exactly the amount of extra-credit I earned. __________

23. I enjoyed doing the experimental tasks that was so absorbing that I forgot about everything else. __________

24. I was strongly motivated be the experimenter's recognition of my performance. __________

25. I had to feel that I was earning something for what I did in the experiment. __________

26. I enjoyed trying to solve complex problems in the experiment. __________

27. During the experiment, it was important for me to have an outlet for self-expression. __________

28. I wanted to find out how good I really could be in doing the experiment. __________

29. I want other people to find out how good I really can be at the experiment. ________

30. What matters most to me is enjoying what I did during the experiment ________

31. The experiment was interesting. ________

32. The experiment was enjoyable. ________

33. I would be willing to come back voluntarily in the future to participate in a similar experiment containing a scenario. ________

Appendix C

Oklahoma State University
Institutional Review Board

Protocol Expires: 10/30/2001

Date : Tuesday, October 31, 2000

IRB Application No: AS0118

Proposal Title: CONCEALED INFORMATION AND FACE RECOGNITION USING BEHAVIORAL AND SPECTRAL ANALYSES

Principal Investigator(s) :

✓Adam Lee Lawson
215 N. Murray
Stillwater, OK 74078

Charles Abramson
401 N Murray
Stillwater, OK 74078

Reviewed and Processed as: Expedited

Approval Status Recommended by Reviewer(s) : Approved

Signature :

Carol Olson, Director of University Research Compliance

Tuesday, October 31, 2000
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modifications to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

2

VITA

Adam Lee Lawson

Candidate for the Degree of

Doctor of Philosophy

Thesis: CONCEALED INFORMATION AND FACE RECOGNITION USING BEHAVIORAL AND SPECTRAL ANALYSES

Major Field: Psychology

Biographical:

Personal Data: Born in Jefferson City, Missouri, On January 24, 1973, the son of Leroy and Shirley Lawson.

Education: Graduated from Conway High School, Conway, Missouri in May 1991; received Bachelor of Arts degree in Psychology from Columbia College, Columbia, Missouri in May 1996; received the Master of Science degree in Psychology from Okalahoma State University, Stillwater, Oklahoma in December 1999. Completed the requirements for the Doctor of Philosophy degree with a major in Psychology at Oklahoma State University in December, 2001.

Experience: Laboratory technician assistant in the Department of Pharmacology School of Medicine at University of Missouri-Columbia, Columbia, Missouri; research in content analysis of Counseling and Values at Columbia College, Columbia, Missouri; research fellow at Oklahoma State University, Stillwater, Oklahoma; employed by Oklahoma State University, Department of Psychology as a graduate assistant and graduate instructor.

Professional Memberships: American Psychological Society, Society for Psychophysiological Research, Sigma Xi.