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# The Psychological Correlates of Asymmetric Cerebral Activation

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# THE PSYCHOLOGICAL CORRELATES OF ASYMMETRIC CEREBRAL ACTIVATION

By

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B.A. East Carolina University, 1992

M.A. East Carolina University, 1994

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

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(in Psychology)

The Graduate School

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August, 2003

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THE PSYCHOLOGICAL CORRELATES OF ASYMMETRIC

CEREBRAL ACTIVATION

By Lisle R. Kingery

Thesis Advisor: Dr. Colin Martindale

An Abstract of the Thesis Presented
in Partial Fulfillment of the Requirements for the
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This study examined the psychological correlates of asymmetric cerebral activation as measured by electroencephalograph (EEG) recordings. Five content areas were investigated in the context of EEG asymmetry: hierarchical visual processing, creative potential, mood, personality, and EEG asymmetry, and the effect of a mood induction procedure on cognition and EEG asymmetry. Undergraduate participants completed two experimental sessions separated by two to three weeks. Participants completed a comprehensive set of emotion, personality, and creative potential measures, a cognitive task assessing individual differences in hierarchical visual processing, and a short form of the Rorschach inkblot test. Additionally, each participant underwent either a happy or a sad mood induction procedure to examine the effects of mood on verbal and spatial fluency tasks and EEG asymmetry. EEG was measured in frontal, central, and parietal locations.

The primary findings regarding the psychometrics of EEG asymmetry suggested that a large proportion of participants show relatively stable EEG asymmetry across two to three weeks. The results failed to replicate previous research suggesting a relationship between hierarchical visual analysis and mood using a Global-Local task. The results also failed to support the hypothesis that the Rorschach could be used as a measure of hierarchical visual analysis. However, Minor Detail location responses on the Rorschach correlated positively with negative affect and negatively with positive affect.

Regarding creativity, the Rorschach was found to be a viable means of assessing individual differences in primary process cognition using the Regressive Imagery Dictionary (Martindale, 1975). Additionally, the results partially supported Martindale's (1999) hypothesis that creative people show greater right-hemisphere activation.

No support was found for the hypothesized relationships between frontal activation asymmetry and mood or personality. Regarding the effect of mood on verbal and spatial fluency, no support was found for the hypothesis that happy moods increase verbal fluency and decrease spatial fluency or that sad moods increase spatial fluency and decrease verbal fluency. Happy and sad mood also did not have a significant effect on EEG asymmetry in the predicted directions. The results are discussed in terms of the status of recent research on EEG asymmetry and its relation to cognition, creativity, emotion and personality.

# ACKNOWLEDGEMENTS

Without the guidance and assistance of many colleagues and loved ones, this work would have never been completed. I would first like to thank the diligent research assistants who assisted in the data collection and execution of this project, including Jaren Bates, Casey Brown, Macklin Gaynor, Johnny Jones, Mindy Oliver, and Audrey Waltz. They certainly deserve more than a few course credits for their efforts and I will always be grateful for their help.

When I started graduate school at the University of Maine, I had no idea that it would lead to working with some of the most inspiring and brilliant intellectual mentors I have ever known. Luckily for me, Geoffrey Thorpe saw that I had potential as a psychologist and accepted me as his student. I have thoroughly enjoyed working with him.

My interest in the topics explored in this research began in Alan Rosenwasser's Physiological Psychology course. I was in search of a topic for the class paper and I stumbled across an article on personality and EEG asymmetry. His interest and positive feedback opened the first door to the development of this project. The next door was opened by Colin Martindale. Colin's impact on my intellectual and professional development has been incalculable and I deeply appreciate his willingness to serve as chair of this project. I would like to express my deep appreciation for the contributions of Marie Hayes and Jonathan Borkum. They both provided invaluable feedback that improved the quality of this research. Sharon Crook deserves special mention because she was kind enough to generously share her time and expertise with a complete stranger from another department.

I would like to express my appreciation to Jonna Kwiatkowski, whose help enabled me to learn how to use an EEG machine. Thanks also to Oshin Vartanian for providing invaluable assistance with obtaining some of the questionnaires used in this study.

For her love, encouragement, and help with all the "details," I would like to thank my best friend and fiancé, Julie Newman. There is nothing that I look forward to more than spending the rest of our lives together. To my brother and sister-in-law, Robert and Maria Kingery, thank you for your constant support and love. Finally, this work is dedicated to my parents, Robert E. and Frances S. Kingery.

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# CHAPTER 1: INTRODUCTION

> The day may come when advances in neurophysiology and electronics will reveal some of the physical correlates of psychic processes. But it should be understood that according to our present conceptions no components of the personality are identified with any particular structures or processes of the brain as we know it, morphologically and physiologically, today. The physico-chemical brain is not the personality, but one of its constitutional determinants. For the present at least, most psychologists will be content to forget the brain and restrict themselves to the psychical-behavioral level of analysis and formulation. (Murray & Kluckhorn, 1948, cited in Maddi, 1971, pg. 49).

Henry Murray was one of the most prominent personality theorists of the 20th Century. Given the status of the scientific understanding of brain functions and personality over fifty years ago, Murray's recommendation for psychologists to "forget" the brain was arguably prudent. Today, however, for anyone seriously interested in personality and related topics (e.g., cognition, emotion, motivation, perception, creativity), this outlook would be ill-advised. Indeed, the day has come when neurophysiology and electronics can provide information about neural correlates of "psychic processes."

## Cerebral Functioning, Cognition, Emotion, Personality and Creativity

The theoretical foundation of the hypotheses in this research rely especially on the integrative, but largely independent work of Martindale (1991, 1999), Ivry and Robertson (1999) and Davidson (1998), among others. The questions posed in this research derive from a broad interest in how the cerebral cortex mediates cognition, emotion, personality and creativity, and how each of these constructs can be assessed. More often than not, these topics are examined in isolation, without reference to complementary literatures.

As will be shown, a consideration of how any one of these areas relates to cerebral functioning inevitably leads to the examination of at least one (if not all) of the others. Thus, emotion is intimately tied to motivation and personality (Meyer & Schack, 1989; Peirson & Heuchart, 2001; Zelenski & Larsen, 2000). Cognitive activity (e.g., hierarchical visual analysis) mediated by parietal-temporal cortex correlates with mood (Basso, Schefft, Ris, & Dember, 1996). Cognition and emotion may interact in interesting ways in the frontal lobes (Bartolic, Basso, Schefft, Glauser, Titanic-Schefft, 1999). And, differences in creative ability, which relate to certain cognitive, mood and personality variables (Ahsby, Isen & Turken, 1997; Russ, 1999), may be influenced by different patterns of cerebral activation (Martindale, 1999).

In this study it will be argued that the areas of conceptual/empirical overlap among cognition, emotion, personality and creativity is due (at least in part) to how distinct regions of the cortex process information. Emerging evidence suggests that the right and left hemispheres, as well as specific frontal, temporal and parietal lobe sectors, play unique roles in the mediation of cognition, emotion, personality and creativity. Unfortunately, very little research has examined these topics in relation to one anther.

The purpose of this study, therefore, is to fill a research void by comprehensively examining the psychological correlates of brain activity. The methods include direct measures of cortical activation (electroencephalograph (EEG) recordings), a select group of empirically supported cognitive, emotional, and creativity tasks, and a comprehensive set of self-report questionnaires measuring fundamental dimensions of personality.

## Brain-Behavior Relationships and Operational Definitions

Studying brain-behavior relationships is theoretically and methodologically challenging. Operationalizing constructs such as "cerebral activation," "emotion," "cognition," "personality," and "creativity" is not readily achieved and it is critical that standardized methods be used. In the present study, EEG recordings were used as an index of cerebral activation because prior research suggests that they relate meaningfully to *fundamental, biologically based dimensions* of mood, personality and cognition that are theoretically linked to relatively distinct regions of the cortex. Measures of EEG asymmetry (i.e., relative activation of the left vs. the right hemisphere) have been shown to relate to a variety of psychological constructs, including emotional disposition (Davidson, 1998), personality (Sutton & Davidson, 1997; Tomarken, Davidson, Wheeler & Doss, 1990), cognitive functioning (Davidson, Taylor & Saron, 1978; Furst, 1976; Glass & Butler, 1977), and creativity (Martindale, 1999). In the present study, baseline and task-related EEG asymmetry measured in frontal, central and parietal cortical areas was assessed to investigate how asymmetric cerebral activation relates to specific "psychic processes."

According to Eysenck (1994), "EEG measures have an important advantage-they are very much determined by genetics. Bouchard (1991) summarizes literature to show identical intraclass correlations across the four classic EEG bands of .80 for monozygotic (MZ) twins brought up apart." (pg. 168). Compared to other measures of brain activity in relation to these topics, EEG is also the least invasive and most extensively used psychophysiological method. In the design of the present study, current methodological recommendations for EEG research were followed (Pivik, Broughton, Coppola, Davidson, Fox, & Nuwer, 1993). These guidelines are outlined in the following paragraphs. The materials used to operationalize each psychological construct of interest were chosen on the basis of their empirical merit and theoretical relevance. As literature relevant to each measure is described, the rationale for including the particular measure will be explained.

## Overview of the Study

The following review is divided into six sections. The first section provides a brief introduction to psychological processes that appear to be differentially processed by relatively distinct regions of the cortex. The second section outlines EEG measurement and important theoretical, procedural and psychometric issues. This introduction is necessary to understand the terms used in this literature.

Section three introduces Martindale's (1991, 2001) neural-network theory of mind, which provides a broad theoretical rationale for hypothesizing that distinct cortical "analyzers" mediate specific dimensions of cognition, emotion, personality and creativity. Martindale's work on creativity and personality will be reviewed, as these topics are central to this research. Based on Martindale's work and the author's interest in psychological assessment, the present study will include a novel approach to testing Martindale's theory of creativity and personality using the Rorschach inkblot test (Rorschach, 1942). It will be argued that Martindale's neural-network theory provides a theoretical rationale for how the Rorschach functions as a unique measure of cognition, personality and creativity. Although Martindale's theory has impressive empirical support, more data are needed concerning the physiological basis of neural networks associated with these topics. This is especially true in light of recent research (Davidson, 1998; Ivry & Robertson, 1999) relevant to emotion, personality and cognition that has not been considered in terms of Martindale's theory of mind.

Section four reviews research on how posterior cortical sectors mediate a specific form of visual perception: hierarchical visual analysis. The idea that the left and right hemispheres differentially process local and global elements of visual stimuli is well known in neuropsychology (Lezak, 1995). However, the physiological bases of these differences are just beginning to be understood. Relying on the work of Ivry and Robertson (1999), this section outlines the Double Filtering by Frequency (DFF) theory, which posits that posterior (e.g., parietal/temporal) regions of the left and right hemispheres are "tuned" to process different, yet overlapping, visual and auditory perceptual stimuli. More specifically, Ivry and Robertson argue that the left hemisphere is tuned to process high-frequency information, and thus acts as a high-bandpass perceptual filter. In contrast, the right hemisphere seems to differentially mediate low-frequency information, and thus acts as a low-bandpass perceptual filter.

According to Ivry and Robertson (1999), differential responsiveness to spatial frequencies embedded in visual inputs can account for a broad array of experimental findings concerning hemispheric differences in processing global and local elements of visual stimuli. In addition to using a commonly used measure of hierarchical visual analysis (Basso et al., 1996), the Rorschach stimuli may also function as a unique measure of hierarchical visual processing. Although Ivry and Robertson's work specifically focuses on visual and auditory *perception* in parietal/temporal cortex, research suggests that their work has implications for theories of language, emotion, personality and creativity (Basso et al., 1996; Coney & Evans, 2000).

Section five moves from a consideration of "psychic" processes mediated by posterior cortex to research suggesting relationships between asymmetric activation of the frontal lobes and emotional, cognitive and personality constructs. The theory of frontal brain asymmetry (FBA; Wiedemann, Pauli, Dengler, Lutzenberger, Birbaumer, & Buchkremer, 1999) has received a considerable amount of research attention. FBA theory posits that the left and right frontal lobes (in conjunction with other brain regions) mediate different aspects of motivation, emotion and personality. Although the data are not entirely supportive of the theory, it is possible that the left frontal lobe mediates approach behavior, positive affect, and hedonic tone (pleasure-displeasure) and that the right hemisphere differentially mediates avoidant behavior, negative affect and arousal (Davidson, 1998). A recent study (Bartolic et al., 1999) based on FBA theory that will be replicated in this study found that happy and sad moods had distinctive effects on verbal and visuospatial fluency performance.

The sixth section is a brief summary and presentation of the hypotheses of the present study. A core theme of the present study is that the work of Ivry and Robertson (1999), Davidson (1999) and others contributes to Martindale's (1999) more encompassing neural-network theory of mind by taking substantive steps toward explaining how relatively distinct regions of the cerebral cortex process mental activity involved in emotion, cognition, and personality. The implications of Martindale's model have been examined more extensively in the areas of sensation, perception, aesthetics and creativity. They have been largely ignored in the areas of emotion, personality and clinical psychology. Thus, more research in these areas, guided by Martindale's theory, is needed. In fact, one could argue that applying Martindale's theories to clinical psychology and personality is very much indicated because his theory provides a viable, empirically based alternative meta-theory to current information processing (Beck &

Clark, 1997), radical behavioral (Hayes, Barnes-Holmes, & Roche, 2001) and psychodynamic (Lerner, 1996) theories in clinical psychology that seem to be less focused on how the brain works.

## Region Specific Cortical Functioning

Although the whole is clearly greater than the sum of the parts when it comes to cortical functioning, the left hemisphere is often characterized as the "sequential, analytical, logical and verbal" processor and the right hemisphere is commonly described as "superior for simultaneous, integrative, intuitive, and spatial tasks." (De Pascalis, 1993, pg. 826). Perhaps the strongest evidence for region specific capacities comes from research on brain-injured patients. Many studies document a variety of cognitive deficits associated with lateralized cortical damage (Kaufman, 1990; Lezak, 1995). Generally, right hemisphere damage disrupts accurate visuospatial processing and left hemisphere damage disrupts verbal functioning. These broad generalizations, however, are tempered enormously by factors such as gender, handedness, age, intelligence, and many other factors (Lezak, 1995).

In comparison to cognition, much less research concerning the effects of brain damage on emotion and personality has been conducted. Some research suggests that left hemisphere damage is commonly associated with heightened emotional and sympathetic nervous system arousal, "catastrophic reactions," impulsivity and depression. Although the underlying physiological reasons for such effects are unknown, some speculate that "the left hemisphere has inhibitory control over other areas responsible for activating arousal systems" or that "the left hemisphere may directly control the limbic or reticular systems." (Heilman & Bowers, 1990. pg. 109, see also Davidson, 1994; Silberman &

Weingartner, 1986). Thus, damage to the left hemisphere may result in a disinhibition of other brain sectors that it otherwise inhibits. Right hemisphere damage, in contrast, is frequently associated with indifference reactions, emotional flattening and other *deficits* in emotional expression, comprehension and evaluation (Heilman & Bowers, 1990; Robinson, Kubos, Starr, Rao, & Price, 1984). Experimental results using healthy participants also point to a variety of differential processing capacities between the right and left hemispheres, including hierarchical visual processing (Ivry & Robertson, 1999), emotion, personality, and creativity (Davidson & Hugdahl, 1995; Martindale, 1999).

In addition to differences in processing capacities between the left and right hemispheres, recent research suggests that the rostral/caudal (i.e., anterior/posterior) cortical dimension may have implications for individual differences (Heller, 1990a, 1990b). Given the evidence for meaningful differences in processing capacities between anterior and posterior cortical regions (Posner & Peterson, 1990), this distinction is not surprising. Anterior cortical sectors are broadly referred to as "executive" regions and the posterior cortex mediates more immediate sensory/perceptual experience (Gazzaniga, 1995; Newman & Baars, 1993). Further support for the anterior/posterior distinction derives from research showing the relative independence of anterior and posterior measures of EEG asymmetry (Papousek & Schulter, 1998). Failure to consider both dimensions results in overlooking the role each section of the cortex may play in individual differences research.

## EEG Measurement

According to Vaughan and Kurtzberg (1992), "In principle, the most valuable information on brain function should be provided by the electrical activity generated by neurons within the functioning brain." (pg. 2). Methodological strengths of EEG recordings as a measure of cerebral activation include their relatively noninvasive nature and their ability to represent brain activity while psychological processes are occurring over time. Most brain imaging technologies (e.g., rCBF, PET, fMRI) provide only very brief measurements and are much more invasive, expensive and time consuming (Lane, Reiman, Bradley, Lang, Ahern, Davidson, & Schwartz, 1997). As with all methods, the promising and unique features of EEG are balanced by some negative features. Duffy (1994) refers to the "darker side" of EEG measurement, which entails "artifact control difficulty, management of huge data sets" (pg. 94) and conceptual/theoretical "conundrums" (Davidson, 1998). The specific means of coping with the challenges of EEG data collection and analysis is described in the Methods section.

EEG recordings are perhaps most strongly associated with sleep and consciousness research and putatively represent the electrical activity of the brain underlying the electrodes fastened to the skull, although this is true only to a limited extent because electrodes do detect signals from a wide field rather than one specific location (Carlson, 1998). Conventionally, EEG waves are separated into bands of varying frequency ranges with distinct average amplitudes (i.e., 1-4 Hz Delta (up to 100-200 μV), 5-7 Hz Theta (<30μV), 8-13 Hz Alpha (30-50μV), 14-20 Hz Beta 1 (<20μV), 21-30 Hz Beta 2 (<20μV)). The band of EEG activity examined in the literature under consideration is predominantly Alpha. Alpha activity is associated with a relaxed state of mind (Carlson, 1998) and is inversely related to cortical "activation." Specifically, more Alpha indicates less activity and less alpha represents more activity. In support of this idea, Cook, O'Hara, Uijtdehaage, Mandelkern, and Leuchter (1998) found a significant negative correlation between Alpha activity and simultaneously recorded PET-derived cortical activation. The present research project will examine all five frequency bands described above so that a comprehensive assessment of the psychological correlates of cortical activation can be made.

Procedural Considerations

Aided by modern computing and electronic technologies, the quantitative analysis of EEG signals and all other biophysical electrical potential sources has become extremely complex. Although many procedural components of EEG measurement are standardized (e.g., electrode location, essential materials, recommended data analytic approaches; Pivik et al., 1993), the measures ultimately derived from EEG recordings, to say nothing of their meaning, are quite diverse (Eysenck, 1994). The broad distinction between spontaneous and evoked-response potential (ERP) is important for conceptual and methodological reasons (Ray 1990). As it relates to this study, spontaneous EEG recordings involve measuring brainwaves over relatively long periods of time (e.g., minutes) and calculating the prevalence of various frequencies (or frequency bands) during a specific time period (or epoch). The procedures involved in extracting prevalent frequencies from complex waveforms are referred to generally as spectral analysis (Ray, 1990). In contrast to spontaneous recordings, ERP recordings focus specifically on the waveform during approximately 800 milliseconds following some stimulus presentation. The methods and literature in the present study are solely concerned with baseline and task-related spontaneous EEG asymmetry measures, not ERP measures.

The Fast Fourier Transformation (FFT) is a common spectral analytic technique and is used as a means of estimating the prevalence of specific frequencies embedded in the raw EEG signal (Ray, 1990). As Martindale (2001) explained, "Fourier (1822) proved that any mathematical function can be created by or decomposed into sine waves combined (adding or subtracting) so that they create the function. Fourier's proof applied not only to one-way functions but to n-way functions" (pg. 28). The output of FFT analyses is a plot of the frequency components against the amplitude of those frequencies. When the FFT results are averaged across all epochs in a given EEG signal, an estimate of the average power contained in the signal for various frequency bands is obtained.

The concepts of spectral analysis and Fourier transformations are not only critical to analyzing EEG data, they are also conceptually related to the physiological basis for some of the processing differences between the left and right hemispheres. As Martindale (2001) described, "It was not until the 1960's that it is was discovered that the visual system does something resembling a two-way Fourier analysis of its inputs (Ginsburg, 1986)." (pg. 28). The basis of Ivry and Robertson's (1999) Double Filtering by Frequency theory of lateralized processing in parietal-temporal cortex is based on the idea that each hemisphere is sensitive to sensory-perceptual information that *is composed of* different patterns of spectral frequencies.

Asymmetry Measures

Although there are a variety of ways of operationalizing EEG asymmetry (Pivik et al., 1993), the most common metric used is Alpha power in the right hemisphere minus Alpha power in the left hemisphere. Using this metric, positive values indicate relatively more activation of the left hemisphere. An important methodological feature with implications for asymmetry research concerns what montage is used. A montage is the pattern of electrode placement on the scalp and the means of referencing each signal of interest. Almost universally, researchers use the International 10-20 electrode system for electrode placement specification.

Referencing an electrical signal refers to the fact that some comparison signal is required to measure brain waves. As Ray (1990) noted, "When a researcher records electrical activity from the brain, it should be noted that one is, in actuality, comparing the signals from two recording electrodes. What is recorded is the signal or rhythm that is not common to both sites" (pg. 396). Two referencing schemes are commonly used: monopolar and bipolar. Monopolar referencing entails comparing each lead (i.e., signal input) to a *single* or common reference. The common reference should be as inactive as possible, which is why comparing each signal to a linked mastoid (bone just behind the ear) or linked earlobes lead is recommended. Bipolar referencing, in contrast, provides EEG data relevant to the *differences* in activity between two *active* sites. Which referencing scheme used is important because each provides different information, as Cacioppo, Tassinary and Fridlund (1990) explain:

> Common (monopolar) reference recording is characterized by (1) a much more general pickup region than bipolar recording and (2) sensitivity to variations in the absolute *level* of electrical activity (assuming the ground electrode reflects an isoelectric state). Bipolar recording, in contrast, is sensitive to variations in the *gradient* of electrical activity between two active electrodes. Due to these distinctions, the selection of the common reference or the bipolar method depends entirely on the question posed by the investigator. (pg. 346, italics in original).

Reliability of EEG Asymmetry Measures

Before a psychological assessment device can be assumed to measure some construct reliably and validly, it must undergo psychometric evaluation. This is no less true for measures of physiological functions believed to be related to psychological traits

(Tomarken, 1995). The empirical and theoretical basis of EEG asymmetry theories depend in large part on the stability and reactivity of asymmetry measures (Eysenck, 1994). In this regard, Tomarken et al. (1992) likened EEG asymmetry to personality trait measurement and examined whether EEG asymmetries were reliable. Evidence for minimally adequate 3-week test-retest reliability ($r$ = .58 to .88) and good internal consistency estimates (coefficient alpha = .90) were obtained, which is consistent with, though somewhat higher than, other EEG asymmetry reliability studies (Debener, Beauducel, Nessler, Brocke, Beilemann, & Kayser, 2000; Papousek, & Schulter, 1998).

Despite these supportive findings for the trait-like nature of EEG asymmetry measures, many factors serve to confound reliable EEG measurement (e.g., level of alertness, signal artifacts, environmental conditions, task demands). For these reasons, some researchers (Davidson, 1998; Pivik et al., 1993) recommend measuring EEG on two occasions so that more reliable estimates of tonic EEG asymmetry can be derived. This recommendation was implemented in the present study.

One final point about EEG asymmetry measurement should be made before moving on to a review of the theories that form the basis for the hypotheses in the present study. As mentioned previously, part of the justification for examining anterior and posterior sites independently derives from research showing that:

> Intercorrelations of EEG asymmetries at different electrode positions suggest that anterior and posterior EEG asymmetries are largely independent measures of cortical laterality. Both this partial independence of activation asymmetries and the differences in temporal stability (posterior asymmetry measures show somewhat greater temporal stabilities) underscore the significance of the anterior-posterior dimension in laterality research and may be one reason for several contradictory observations in studies on brain laterality. (Papousek & Schulter, 1998, pg. 87).

Introduction to Martindale's Neural-Network Theory of Mind

Martindale (1981, 1991, 2001) has proposed a neural-network theory of mind that has demonstrated explanatory and heuristic value in a wide range of fields, including aesthetics (Martindale, 2001), the evolution of art (Martindale, 1990), personality (Martindale, 1980), creativity (Martindale, 1999), memory, language, learning, problem-solving (Martindale, 1991) and consciousness (Martindale, 1981). Although Martindale's theory applies to all types of mental phenomena, the focus of this research specifically concerns his theory of creativity and his theory of personality.

Based on a large amount of research in experimental psychology and psychophysiology, Martindale argues that the brain is composed of a collection of analyzers devoted to specific psychological functions. These analyzers function as feature-detection systems (Martindale, 1980) and operate according to the principles of neural-network theory. According to Martindale (1991), "A neural-network or parallel-distributed process model of cognition is aimed at explaining how and why we experience mental phenomena" (pg. 11).

Martindale's (1991) theory is complex, so only a very general description will be provided here. Mental activity is thought to be an emergent property of a large number of neural networks or analyzers "devoted to a specific subtask" (pg. 46). Each network is defined by "cognitive units (i.e., nodes)...a state of activation...a pattern of connections among nodes...activation rules for the nodes...output functions for the nodes...learning rules...(and) an environment for the system" (Martindale, 1991, pg. 12-13).

As Martindale (2000) explained,

> Neural network theories ultimately have only one explanation for everything: how activated the nodes involved in a phenomenon are. Why do we perceive something? Because a stimulus activated the relevant nodes. Why are we attending to this rather than that? Because the nodes coding this are a lot more activated than the nodes coding that. Why do we remember something? Because the nodes coding it are sufficiently activated. Why do we forget something? Because the nodes coding the to-be-remembered item are not activated enough. Essentially all positive or desirable cognitive outcomes are explained in terms of maximizing activation and minimizing inhibition. (pg. 4-5).

Stages of Mental Processing

Trying to explain how and why we experience mental phenomena is obviously an ambitious undertaking, so Martindale breaks the process down into intuitively meaningful, and empirically supported stages. Very generally, mental phenomena begin with sensory analyzers and flow back and forth through perceptual, conceptual, and motor response systems. Each analyzer is constructed in the same way, based roughly on the structure of the cortex. That is, each analyzer has several layers and each layer has a "large number of nodes" (Martindale, 1991, pg. 47). Nodes are connected to one another vertically and horizontally. Vertical connections are almost always excitatory and lateral connections are almost always inhibitory. Furthermore, "the principle of arrangement of any layer of an analyzer is one of similarity: the more similar the thing two nodes code, the closer together they are; hence, the more they laterally inhibit one another" (pg. 47). Note that higher levels of the analyzer have more nodes and code more specific things. The lower levels have fewer nodes and code more abstract features of mental activity.

There are many other proposed analyzers, such as visual-object, facial, auditory, musical melody, motion, color and form analyzers. More specific details about the functioning of these analyzers is beyond the scope of this summary, and the reader is referred to Martindale (1980, 1991) for a full description. Theoretically, each analyzer is "tuned" (electrochemically) to respond to particular forms of stimuli.

Bottom-Up versus Top-Down Activation

Martindale (1991) and others (Shepard, 1984) distinguish conceptually between bottom-up and top-down activation of nodes. Bottom-up activation concerns relatively direct coding and perception of sensory input. Top-down activation concerns arousal of nodes as a result of mental images, expectations, goals and conceptual analyzers. Martindale uses these concepts to explain hallucinations, images and dreams (1991, see pp. 63-68). Although sensory, perceptual and conceptual (e.g., action, semantic) analyzers are distinct, they are tremendously interconnected.

As an example, if someone shows you a shoe, asks you what it is, and you say "a shoe", your bottom-up processes are working properly. If someone shows you a shoe, asks you what it is, and you say "a fig newton", either (a) your bottom up processing was not working properly (e.g., brain damage) or (b) your accurate bottom-up processing was superseded by some form of top-down processing (e.g, psychosis). This seems clear when unambiguous stimuli are perceived, but what happens when ambiguous stimuli are perceived? Theorists from a variety of fields suggest that some form of *interpretation* occurs. For example, Schacter and Singer's (1962) theory of emotion is based on this idea in that internal ambiguous stimuli promote cognitive appraisals. Gibson's theory of ecological perception is also in part based on this idea (see Shepard, 1984). Theoretically, top-down processing helps account for why reality, to some extent at least, is socially constructed. (Martindale, 1991).

In summary, Martindale has outlined a heuristic and experimentally supported model of how the brain processes "psychic" processes. His work on creativity and personality are the specific focus of the present study, and are discussed below.

Biological Basis of Creativity

A major component of Martindale's (1999) theory of the biological basis of creativity is that more creative people have greater access to primary process cognition, and that this form of cognition is especially mediated by the right hemisphere. According to Martindale (1999):

> The primary process-secondary process continuum is the main dimension along which cognition varies. Primary process thought is...autistic, free-associative, analogical and characterized by concrete images as opposed to abstract concepts. Secondary process cognition is the abstract, logical, reality-oriented thought of waking consciousness (pg. 138).

To date, few studies have used direct measures of cerebral activation to examine Martindale's theory of creativity, and only one study has used EEG measures of hemispheric activation to investigate its relation to primary process cognition.

To test the hypothesis that greater right hemisphere activation would correlate with primary process cognition, Martindale, Covello and West (1986) examined parietal EEG alpha asymmetry measures in 23 undergraduate males under three conditions: baseline (5 minutes), creative story development (5 minutes) and writing out the story (15 minutes). The stories were analyzed for primary process content using Martindale's Regressive Imagery Dictionary (RID). The RID is a computer program which analyzes the content of text and provides measures of primary and secondary process cognition. It contains 2,900 words and has been validated as a measure of primary process cognition in many studies (Martindale, 1990). Primary process words fall into one of the following five categories: drive, perceptual disinhibition, sensation, regressive cognition and Icarian imagery. Secondary process is referred to as conceptual thought. A fundamental assumption of the RID is that "A person's state of consciousness or type of thought will be reflected in language content so that the latter can be used to measure the former" (Martindale et al., 1986, pg. 80).

The results of this study were clear. Amount of primary process content in the stories correlated significantly ($r = -.61, p < .01$) with the *baseline* EEG asymmetry measure, with positive asymmetry equaling greater left-hemisphere activation. The correlation between EEG asymmetry and primary process for the time when subjects were mentally developing their stories was also significant, but lower ($r = -.42, p < .05$). The correlation was not significant for the writing condition. These results were interpreted to suggest that "people who tend in general to have a lot of right-hemisphere, as compared to left-hemisphere, activation tend to think in a more primary process manner, regardless of their asymmetry while actually thinking or writing" (Martindale et al., 1986, pg. 83).

This study strongly supports the hypothesis that relatively greater right hemisphere activation compared to left hemisphere activation, at least in parietal areas, is associated with greater access to primary process cognition. Only one other study has examined EEG asymmetry and creativity (Martindale, Hines, Mitchell & Covello, 1984) and the results of the three experiments within this study supported the hypothesis that creative people show greater activation of the right versus the left hemisphere. Importantly, this was true *only during creative task performance* and not during baseline or noncreative task performance. These findings were interpreted as supportive of the idea that creative people have greater access to primary process cognition (mediated more by the right hemisphere) and that differences in cerebral activation between creative and uncreative people are observed only during creative task performance (Martindale et al., 1984). In other words, only when they are required to engage in creative thought will creative people show greater levels of right-hemisphere activation compared to left-hemisphere activation. More evidence is needed to determine whether or not greater right hemisphere activation is a general trait of more creative people or whether greater right hemisphere activation in more creative people is task-dependent.

Measuring Creativity

To examine individual differences in creative potential by task-performance interactions experimentally, Martindale has relied on a variety of procedures. Creative tasks have involved constructing creative stories (Martindale & Hasenfus, 1978), responses to Thematic Apperception Test stimuli (Martindale et al., 1984), artistic production (Martindale et al., 1984), alternate uses tests (summarized in Martindale, 1977-1978) and different forms of speech varying in terms of degree of complexity (Martindale & Hasenfus, 1978). In addition to the use of traditional measures of creative potential, the present study used a novel means of testing the relationship between primary process cognition, EEG asymmetry and creative task performance, namely, the Rorschach Inkblot test (Rorschach, 1942).

The current study used a subset of stimuli from the Rorschach to quantify individual differences in primary process cognition. Before outlining the rationale for choosing this method as a measure of primary process and *as a creative task in and of itself*, it is necessary to provide some background information about the Rorschach.

The Rorschach has been described as one of the most controversial assessment tools in the history of psychological assessment (Hiller, Rosenthal, Bornstein, Berry, & Brunell-Neuleib, 1999). Herman Rorschach, a Swiss psychiatrist, developed the test as a means of providing information about a person's perceptual and associative psychic processes (Rappaport, Gill & Schafer, 1945). The Rorschach consists of 10 inkblots on cards. Each card is different in terms of form, color, and shading. Cards VIII, IX and X are all color and cards II and III have some parts with a red hue. Each image differs in terms of how relatively unified (I, II, IV, V, VI, IX) versus how differentiated (III, VIII, X) the overall form of the blot is. Administration and scoring of the Rorschach is standardized according to the Comprehensive System (CS: Exner, 1991).

Critics of the Rorschach argue that it is unreliable, invalid and inefficient (Lilienfield, Wood & Garb, 2000). Some have even called for a "moratorium" on the use of the method in clinical and forensic, but not research, contexts (Garb, 1999). Proponents of the technique, of course, argue that critics are at best empirically and theoretically misinformed and at worst intentionally misrepresenting the contemporary scientific status of the method (Meyer, 2000). As with many controversial issues, the truth probably lies somewhere in the middle. Even the most severe critics acknowledge that the Rorschach has demonstrated some empirical support, especially as a measure of psychotic thought processes (Wood et al., 1999). And, proponents of the Rorschach are quick to point out its limitations (Meyer, 1999a).

Rather than considering all of the arguments from these opposing "camps," the following paragraphs will focus specifically on the empirical and theoretical rationale for using the Rorschach as (a) a measure of primary process cognition and (b) as a creative task in and of itself.

The reason to consider the Rorschach as a measure of primary process cognition is straightforward: prior empirical research consistently confirms a positive relationship between primary process content on the Rorschach and creative ability (Dudek, 1968, 1999). On the Rorschach, primary process cognition manifests itself through responses to the inkblots that include a variety of themes that map neatly onto the dimensions assessed by Martindale's Regressive Imagery Dictionary (e.g., perceptual distortion, regressive cognition, drive contents). Unfortunately, no research to date has analyzed Rorschach responses using the Regressive Imagery Dictionary. Preliminary results from a pilot study conducted in preparation for this dissertation suggest that this is a viable method.

The reason Rorschach-type stimuli could serve as a viable analogue creative task is that the *task demands* are similar to analogues used in prior EEG/creativity research. Many of the tasks used by Martindale and colleagues require the production of verbal material in response to *novel and/or ambiguous stimuli* (e.g., Thematic Apperception Test responses, create-a-story tasks, "tell me all the uses you can think of for a brick"). The use of tasks that involve subjective responses to ambiguous stimuli is important, in part, because creativity is defined as the development of novel and useful ideas (Martindale, 1991). Given an ambiguous visual stimulus, it is expected that creative individuals would provide more novel responses than less creative individuals. Also, the Rorschach is unique in that it includes a strong visuospatial component, as compared to some other creative tasks that are more verbally loaded.

Empirical Rationale for Using Ambiguous Stimuli

Evidence from a wide variety of sources supports the use of ambiguous stimuli as a unique method of assessing a variety of psychological constructs. For example, in one study that examined EEG correlates of emotion and "cognitive bias" (a very popular construct in clinical psychology; see Westling & Ost, 1995), Sutton and Davidson (2000) remarked:

> Many cognitive tasks using affective stimuli have been developed to assess potential memory, attentional, judgmental, associative, and response biases that may be disorder specific. (For example)... clinically anxious individuals have been shown to exhibit stronger tendencies to *interpret ambiguous stimuli* in a threatening manner (e.g., selecting 'die' over 'dye' when hearing a homophone). It is our contention that cognitive biases such as these in affective style are related to stable, broad individual differences in affective style that may, in more extreme instances, confer a vulnerability to psychopathology (pg. 1731, italics added).

In sum, this brief but eclectic assortment of research and theory supports the use of ambiguous stimuli in general, and the Rorschach images specifically, as a means of learning about psychological processes. Not only might the Rorschach tell us something about creativity, but it also may tell us something about personality. This argument makes sense when considered from the perspective of Martindale's theory of personality, which he calls the "Action System".

Martindale's Theory of Personality: The Action System

Knowledge concerning the sensory, perceptual, and certain conceptual analyzers (e.g., semantic memory) is more advanced than knowledge about the action system. In fact, *almost no research on the action system from Martindale's perspective has been conducted.* This is surprising given that the action system could just as easily be called "personality," as Martindale outlined over 20 years ago (Martindale, 1980). In his own words, "There must be something like the action system, but we do not know much about its structure" (Martindale, 1991, pg. 60).

By extrapolating from the structure and function of neural-networks in other mental processes (e.g., sensation, perception), Martindale suggests that personality is made up of subselves, each of which is composed of action, script, disposition, and subself units. In this way, personality is conceptualized in the same way as other mental activities. That is, when neural networks coding specific subself nodes are more highly activated, behavior and mental activity consistent with the theme of the subself will become predominant. Also, activation of certain subselves results in the inhibition of alternate subselves (e.g., one is generally not extraverted and introverted at the same time). Importantly, this model accounts for the fact that situations *elicit* certain subselves. That is, through experience certain situations literally become triggers for the activation of specific subselves; just as other environmental events stimulate specific nodes that are "tuned" to react to such events. Thus, this model accounts for the "person-situation" debate in personality theory (Martindale, 1980).

Although few researchers have formally used his terminology and theoretical framework, the concepts and ideas suggested by Martindale overlap considerably with other information processing constructs (e.g., schema), object relations perspectives (e.g., internalized object representations; Lerner, 1996) and social psychology theories of the self and interpersonal relations (Tesser, 1995).

If Martindale's action system is a viable model of personality rooted in experimental psychology, why has it received such little empirical scrutiny? One reason why the action system has been neglected empirically may be that Martindale has not outlined a specific method for assessing personality. How do we know what "action dispositions," "scripts," and "subselves" are most easily activated in a particular person? Many methods could conceivably be applied, such as behavioral observations, observer-ratings, self-report questionnaires, and language samples (e.g., thought listing, free associations). In addition, Martindale's theory may be able to account for how "projective" techniques work and these techniques may provide useful information about an individual's action system (Martindale, personal communication, 2001). This is actually not surprising, given that Martindale drew on the work of Henry Murray (1938), the developer of the Thematic Apperception Test.

When asked what an ambiguous stimulus *might be*, it is assumed that top-down processing that may be related to the action system is engaged. In other words, a person has to use their conceptual analyzers to make sense of the stimulus and "create" a response. Based on this idea, it is argued that the Rorschach (among many other methods, structured and unstructured/ambiguous) could be used to tap into the action system because it is assumed that the form and content of the *interpretations* will be based in part on the most activated or sensitive nodes in the action system.

Limitations

A few limitations of Martindale's model are important to emphasize. As mentioned above, the anatomical and physiological features of lower level analyzers (e.g., sensation, perception) are arguably better established than analyzers related to conceptual and action systems. Also, although showing an avid interest in lateralization as it relates to creativity (Martindale et al., 1986; Martindale, 1999), the implications of lateralized cortical structure and function as are not extensively discussed in his introductory text on cognitive psychology (Martindale, 1991). Thus, research concerning these topics could help to expand and refine his system.

## Hierarchical Visual Processing and Parietal Cortical Functioning

As described earlier, research concerning how posterior cortical regions mediate a specific form of visual processing (e.g., hierarchical visual analysis) is relevant in the context of Martindale's general theory and is a major focus of the present study. Although not explicitly discussed by Martindale (1991), hierarchical visual analysis may qualify theoretically as a distinct perceptual analyzer. The theory and research underlying the hypotheses for the second component of this study is based on the integrative work of Ivry and Robertson (1999) and a specific study by Basso et al. (1996).

### Double Filtering by Frequency (DFF) Theory

Ivry and Robertson (1999) comprehensively reviewed the experimental literature on hemispheric differences in auditory, visual and language *perception* and proposed the Double Filtering by Frequency (DFF) theory. According to this theory, "the basic dichotomy between processing high and low frequencies provides a parsimonious way to account for a wide range of laterality effects obtained in a range of tasks using more complex visual and auditory stimuli" (pg. 57). DFF theory posits that parietal-temporal cortex functions, at least in part, as a staged filter of inputs, with the right hemisphere preferentially mediating lower frequency information and the left hemisphere preferentially mediating higher frequency inputs. The precise meaning of lower and higher frequency information depends on the sensory/perceptual system. Higher frequency auditory information is relatively straightforward, with frequency being directly related to pitch. Conceptualizing visual information in terms of spatial frequency is more difficult, and depends on the specific visual stimuli. Generally, lower-frequency information is described as global and higher-frequency information is described as local (e.g., details).

DFF is a staged model because three basic stages of processing are proposed: sensory representation, selective filtering of task-relevant information, and asymmetric filtering by cerebral hemisphere of selected information. Importantly, Ivry and Robertson (1999) suggested that asymmetric filtering is more evident on tasks requiring higher-order (pg. 64-65) processing, rather than initial sensory representation or selective attention tasks.

DFF theory does not propose a strict dichotomy between hemispheric processing; both hemispheres share in representing midrange frequency information. DFF theory does predict that the left hemisphere is particularly poor at representing low frequency information and the right hemisphere is particularly poor at mediating high frequency information. Stated differently, the two hemispheres may be tuned to different frequency responses (i.e., high-left, low-right).

As Ivry and Robertson (1999) show in their review, experimental tasks used to assess hierarchical (i.e., global-local) visual processing are numerous and vary from simple sinusoidal gratings to complex visual scenes. A key principle of DFF theory is that global-local relations must be considered relative to each other rather than absolute. This point is illustrated by the simple fact that changes in the number of objects, distance from view, visual complexity and other factors, all contribute to the evaluation of global-local features in visual perception. For this reason, the term hierarchical visual processing is preferred over global-local processing. Although Ivry and Robertson briefly consider the implications of DFF theory for some forms of psychopathology (e.g., schizophrenia. alcohol intoxication, and dementia), they do not consider the link between their theory and recent research on global-local perception and emotion. Ivry and Robertson barely mention Davidson's work and there is no mention of personality or EEG laterality studies. Not surprisingly, Martindale is not cited.

Hierarchichal Visual Processing and Emotion

Basso, Schefft, Ris, and Dember (1996) tested whether dispositional mood was related to hierarchical visual analysis. Citing experimental and neuropsychological research suggesting a relationship between left-hemisphere perceptual processing biases and measures of distress and right-hemisphere perceptual processing biases associated with positive traits (optimism, lack of distress), they hypothesized that anxiety and depression would be associated with left hemisphere information processing biases and thus should be related with local visual processing biases. Conversely. they hypothesized that optimism and subjective well being would be related to relatively greater right hemisphere perceptual processing biases (global bias).

To examine this idea, Basso et al. (1996) correlated self-report measures of depression, anxiety and optimism with performance on a simple visual perception task. This study found significant correlations between self-reported mood and tendencies toward global versus local visual processing such that trait anxiety correlated -.65 with global responses and depression correlated -.45 with global responses. Conversely, they found a significant positive correlation ($r$ = .49) between a measure of optimism and global response preferences.

Hierarchical Visual Processing and Personality

In addition to suggesting a link between mood and hierarchical visual processing, Basso et al. (1996) suggested that global-local processing biases may also relate to neuroticism and other personality traits. Citing Shapiro (1965), they hypothesized that a global orientation is associated with histrionic, vague, and excessively impressionistic perceptual processing. On the other hand, excessive attention to detail (i.e., local elements) is associated with an obsessive-compulsive personality style, as well as anxiety and pessimism.

Other research supports a connection between differences in lateralized processing and personality. Charman (1979) associated differences in extraversion/introversion with lateralized sensory memory processing. Using an iconic memory task of matrices of letters in either the left or right visual field, Charman found that extraverts process information in a "quicker, holistic or impressionistic manner whereas introverts process information in a slower analytic manner" (pg. 656-657). Importantly, the results also indicated a significant personality by visual field interaction. Specifically, introverts showed better memory on right visual field trials (left hemisphere) and extraverts showed relatively better memory for left visual field (right hemisphere) iconic memory. These results point to a specific personality x hemisphere interaction with respect to information processing such that introverts, relative to extraverts, have more efficient left hemisphere sensory processing and vice versa.

Levy, Heller, Banich, and Burton (1983) noted that "Hysterical conversion symptoms (thought to arise from global repression) occur predominantly on the left side of the body." (pg. 332). Levy et al. also cite data showing that a "hysteric" personality style is associated with greater leftward eye movements and obsessive-compulsive style is more often associated with rightward eye movements. Based on these studies, it is reasonable to hypothesize that global perceptual processing tendencies will be more characteristic of extraverts than introverts. Unfortunately, very few recent data are available to evaluate these ideas in the context of empirically supported measures of personality and contemporary EEG asymmetry measures.

Assessing Hierarchical Visual Analysis

The present study will help address this gap in the literature by including the measure of hierarchical visual analysis used by Basso et al. (1996). Also, there are reasons to think that the Rorschach stimuli may function as a unique measure of hierarchical visual analysis. This is because the task requires the subject to choose some location for their response. *Location is coded either W (whole blot), D (major detail) or Dd (minor detail).* These locations are *standardized* in the Comprehensive System (Exner, 2001). Indeed, some research suggests that location responses may be related to parietal lobe functioning, which provides a link between Rorschach responses and DFF theory.

Within the field of personality and neuropsychological assessment, Perry and Potterat (1997) comment on parietal functions and their relation to the location of Rorschach responses. These researchers stated:

> Damage to either hemisphere would impair a person's ability to identify the Rorschach stimuli and integrate a coherent response. Specifically, we would speculate that damage to the posterior area of the left hemisphere would render an individual unable to process the fine details of the Rorschach inkblot, resulting in an exaggerated preference for producing whole response (W)...In contrast, an individual with right hemisphere damage would not offer an integrated whole response, but instead, would extrapolate a response based on small details (pg. 560).

They go on to provide clinical case descriptions of two neurologically impaired patients whose Rorschach records were consistent with their predictions.

The only well-controlled study that provides data to address the question of how location responses are influenced by cortical damage was conducted by a Russian researcher (Belyi, 1982). This study compared the Rorschachs of 4 equal sized (N=35) groups of brain-damaged adults. Each group had specific lesions to either the left frontal, left parieto-temporal, right frontal, or right parieto-temporal lobes. Contrary to Perry and Potterat's predictions, no significant differences among the groups were evident for the percentage of W responses, although the right hemisphere group (frontal and parieto-temporal) produced significantly more poorly formed W responses (Belyi, 1982).

Although Perry and Potterat (1997) do not predict differences on the use of major details (D) in lateralized brain damage, Belyi's data show that compared to the right parietal groups, patients with left parietal damage produced significantly *more* D responses. When the means are examined across all groups (there were no differences between left and right frontal groups), it appears that damage to the left parietal lobe resulted in an increase in D responses among this group only.

The data concerning unusual detail responses (Dd) is intriguing. Instead of left parietal damage producing a *decrease* in Dd responses compared to the other groups (as predicted by Perry and Potterat based on the idea that left parietal lobe mediates local visual features), it appears that damage to the right parietal lobe resulted in a substantial *increase* in Dd responses. It is clear that only an *increase* in Dd responses occurred in this group because the percentage of Dd responses in all the other groups was consistent with normative expectations. Thus, left parietal damage did not reduce Dd, but right parietal damage was associated with an increase in this location response (Belyi, 1982).

Collectively, these results do not support Perry and Potterat's theory of how location responses relate to posterior cortical damage. Perry and Potterat assume that because right parietal regions relate to holistic processing, right hemisphere damage should reduce W (supposedly holistic) responses. Belyi's data suggest that the absolute number of W responses does not decrease with right damage, although the quality of the responses does. Also, Perry and Potterat assume that damage to the left parietal hemisphere would lead to an *increase* in W responses, because the left hemisphere is associated with processing more detailed information (i.e., high frequency information in DFF terms) and damage to this hemisphere would result in a bias toward W responses. Again, Belyi's data do not support this assertion because all groups showed similar overall percentages of W responses.

Compared to Perry and Potterat's right equals whole, left equals detail model of Rorschach location responses and cortical processing, DFF theory may be able to better account for Belyi's (1982) findings. As noted earlier in the context of DFF theory, the *nature of the stimulus* used has a tremendous impact on hierarchical visual processing, and DFF theory specifically states that hierarchical visual analysis depends on the structure of the stimulus. That is, "how the hemispheres amplify information is one of relative scale rather than absolute scale" (pg. 36). Thus, when considering Rorschach inkblots, one must ask how hierarchical visual analysis should be defined (i.e., what are "local" and what are "global" responses?). At first glance, one would expect that the continuum of location specificity would range from Dd to D to W. This is consistent with Perry and Potterat's view that right damage would interfere with W responses and left damage would interfere with Dd responses and with the view that right=holistic and left=detail. However, when one carefully considers the structure of the inkblots, another possibility arises.

Because of the structure of the blots, each one "pulls" for a certain type of location response. Thus, card I, IV, V, VI, VII and IX all pull for W, and to a lesser extent, D, responses, because they are *relatively unified* stimuli. On the other hand, cards II, III, VIII, and X are relatively "broken" images, with many *discrete elements* making up the entire image. These discrete blots pull more for D responses. Thus, one cannot assume that all of the blots equally assess hierarchical visual processing because each image is structured differently.

When the Rorschach blots are considered from this perspective, a modification of W=right and Dd=left theory arises, depending on which blots to which one is referring. In terms of overall shape, the 6 unified blots would be characterized as predominated by lower frequency in that there is little relative small scale information in the stimulus. The 4 more discrete blots, however, inject more higher-frequency information into the visual stimulus to the extent that smaller scale components are present. In other words, although the overall relative area of all the blots is similar, the 4 discrete blots have more smaller scale elements, thus enabling greater pull as a *higher-frequency stimulus* input.

Revisiting predictions concerning parietal functions and location responses on the Rorschach leads to the following hypotheses. If the left parietal cortex is biased toward high frequency information processing, then W responses on the discrete blots may be more dependent on left-hemisphere processing. In order to make a W response to discrete blots, one must rely more on higher-frequency information processing (i.e., consideration of the discrete areas in relation to one another). Thus, rather than reflecting a right hemisphere function, some W responses, especially on discrete blots, may actually depend more on left-parietal processing than right parietal processing. In contrast, D (Major Detail) responses to relatively discrete blots may be related more to right hemisphere processing because they rely less on the use of higher frequency information. Dd responses would be associated with higher-frequency information processing for all cards. The present study specifically examines differences between subgroups of the inkblots based on whether they tend to elicit Whole or Major Detail location responses.

## Anterior Cortical Functioning, Cognition, Emotion, Personality, and Creativity

According to the theory of frontal brain asymmetry (FBA) proposed by Davidson (1998) and others, the left prefrontal cortex mediates positive mood states and approach behavior and the right frontal lobe mediates negative mood states and avoidance/withdrawal behavior. In their program of research in this area, Davidson and colleagues have utilized the following two design strategies: "The first...assesses whether the index (EEG asymmetry) predicts emotional reactivity to specific stimuli or situations. The second approach assesses whether the biological index maps onto individual differences in fundamental dimensions or typologies of emotion." (pp. 676-677). Examples of research using both strategies are described in the following paragraphs.

Research support for the FBA model is impressive, but not without critics (Hagemann, Naumann, Becker, Maier, & Bartussek, 1998; Reid, Duke, & Allen, 1998). Empirical tests of FBA theory have included infants (Davidson & Fox, 1989; Dawson, Frey, Self, Panatiotides, Hessl, Yamada, & Rinaldi, 1999; Fox & Davidson, 1987), adults (Davidson, 1998), elderly subjects (Kline, Blackhart, Woodward, Williams, & Schwartz, 2000), adolescent boys and girls with anger problems (Harmon-Jones & Allen, 1998), college students (Tomarkin et al, 1992a) and even chimpanzees (Parr & Hopkins, 2000) and rhesus monkeys (Kalin, Larson, Shelton, & Davidson, 1998).

A broad range of topics have been researched in the context of FBA theory, including depression (Debener, Beauducel, Nessler, Brocke, Beilemann, & Kayser, 2000; Henriques & Davidson, 1990), panic disorder (Wiedemann, Pauli, Dengler, Lutzenberger, Birbaumer, & Buchkremer, 1999), social phobia (Davidson, Marshall, Tomarken, & Henriques, 2000), personality (Tomarken & Davidson, 1994), the effects of exercise (Petruzzello & Landers, 1994), the effects of nicotine/smoking (Speilberger, 1989), immune functioning (Davidson, Coe, Doski, & Donzella, 1999; Kang, Davidson, Coe, Wheeler, Tomarken, Ershler, 1991), and other topics (Cacioppo, Petty, & Quintanar, 1982; Drake & Seligman, 1989; Kline, Blackhart, Woodward, Williams, & Schwartz, 2000; Sobotka, Davidson, & Senulis, 1992). Given that this vast amount of work cannot be discussed comprehensively, only studies concerning emotion and personality that are most relevant to the present study are reviewed in this section.

Emotion and Frontal Lobe Activation

In a seminal article, Tomarken, Davidson, Wheeler and Doss (1992) tested whether frontal EEG asymmetry was related to individual differences in self-report measures of positive and negative affect (Watson, Clark & Carey, 1988). The experiment found that when a sample of undergraduate females was divided into reliable left asymmetry versus reliable right asymmetry groups (using frontal (F3-F4) and anterior temporal (T3-T4) leads), the left asymmetry group reported significantly more positive affect and subjects with stable right asymmetry reported more negative affect.

These results must be qualified by a few limitations, however. First, the predicted relationship between asymmetry and affect was only evident for a subgroup of participants (n = 21, out of 79) that showed reliable EEG asymmetry measure over two sessions separated by three weeks. Thus, Tomarken et al. (1992) suggested that "a methodological strategy involving the selection of those subjects who manifest stable asymmetry will yield optimal prediction of affective and other measures" (p. 685). Also, the results overall were much stronger in the anterior-temporal (T3-T4) leads versus the midfrontal (F3-F4) leads. For the anterior-temporal leads, left frontal asymmetry correlated robustly with positive affect ($r = .49$) and also with a measure of the difference between positive and negative affect (PA minus NA), which provides an index of a "pleasure-displeasure" dimension of emotion. Negative affect was negatively correlated with left frontal activation, but not significantly ($r = -.29$, $p = .10$). Also included was a measure of affect intensity (Larsen & Diener, 1987), which did not relate to any frontal EEG asymmetry measures.

In their discussion, Tomarken et al. (1992) note that although their findings were promising, "it is necessary to examine precisely what affective dimension particular patterns of brain activation best map onto" (pg. 684). Indeed, based on the finding that the positive minus negative affect scale correlated significantly with left frontal activation, these researchers noted that including an explicit measure of this "pleasure-displeasure" dimension seems warranted.

In a study testing whether FBA predicted emotional reactivity to films intended to induce happiness or disgust, Wheeler, Davidson and Tomarken (1993) have shown that for females with stable EEG asymmetry (N=26) across two testing sessions, relative left frontal activation predicted more positive responses to happy films and relative right frontal asymmetry predicted more negative responses to disgust films.

Several additional studies have supported FBA theory. Ahern and Schwartz (1985) were among the first to demonstrate changes in frontal EEG asymmetry were associated with positive and negative emotion. They found that while completing emotion/cognition specific tasks (e.g., Happiness-Verbal= "Give me a synonym for the word 'happy.'" or Sadness-Spatial= "Picture the last funeral you went to. From which side of the room did you enter?", pg. 747), EEG frontal asymmetry showed greater relative activation of the left frontal region during happy tasks and greater relative right frontal activation during negative affect (fear and sadness) inducing tasks. Additionally, this study found that after controlling for emotional content of the verbal and spatial tasks, posterior EEG asymmetry correlated with verbal and spatial task performance such that during verbal tasks, left *parietal* EEG was relatively more active than right parietal regions, and vice versa for spatial tasks. The authors cite other research consistent with these verbal/spatial - parietal lobe asymmetry findings (Davidson, Taylor & Saron, 1979; Furst, 1976).

More recently, Sutton and Davidson (2000) tested the hypothesis that resting frontal asymmetry would predict "evaluation of stimuli that differ in affective tone" (p. 49). These researchers used a word-pairing task that involved word pairs of different affective tones (neutral, positive and negative). Twenty-four sets of words for each of the three word pair combinations (neutral-positive, neutral-negative, positive-neutral) were used, and on each trial two pairs of words appeared on a computer screen. The subject was instructed to choose the word-pair that "went together best" (p. 50). Sutton and Davidson reasoned that this type of cognitive task may tap into a cognitive bias for positive vs. negative associations, and thus should relate to frontal EEG asymmetry.

The results supported their predictions, in part. The correlation between EEG frontal asymmetry in the most anterior regions of the scalp (F1/F2) and a "positivity index" calculated from the word-pair associations was significant, but fairly low ($r = .29$, $p < .01$, N = 81). Also, when males and females were examined separately, the correlation remained significant only for females ($r = .39$, $p < .01$; males was $r = .13$). The correlation between midlateral frontal asymmetry and the positivity index approached significance ($r = .20$, $p < .07$). Finally, although ingenious, the method used to assess cognitive bias lacks ecological validity or any prior construct validation as an emotion related task. Despite these limitations, this study does add to the growing body of evidence for a link between certain types of "biased" information processing and emotional/personality phenomena and that ambiguous stimuli may be worthwhile in eliciting such biases.

The only truly experimental investigation that manipulated frontal EEG asymmetry was recently reported (Allen, Harmon-Jones, & Cavender, 2001). This study examined the effect of frontal EEG biofeedback (F3-F4 electrode locations) on emotional experience and facial muscle activity in response to happy, neutral and sad films. Using a sample of 18 undergraduate women, the results showed that those assigned to a "left asymmetry" biofeedback group (i.e., biofeedback to increase left frontal relative to right frontal activation completed every day for five days) reported more positive affect in response to a happy film and a neutral film. Right asymmetry training did not result in a relative increase in negative emotions in response to the sad film.

Another relevant study supporting FBA theory, although not using EEG, was conducted by Thayer and Cohen (1984). They found that listening to sad or positive music influenced electromyographic (EMG) activity, such that during positive emotional states, right arm (forearm extensor) muscle activity and left-sided facial activity (corrugator, brow) was greater, and that during sad emotional states, right-sided brow activity was greater. They concluded that "Accumulating evidence for the ipsilateral innervation of the brows together with the known contralateral innervation of the arms suggests that the pattern of EMG activity in the present study supports the hypothesis of differential hemispheric lateralization for positive and negative emotion." (pg. 266).

It must be noted that a few very well conducted studies have either not supported FBA theory or contradicted it. Thus, although Henriques and Davidson (1990) found that compared to normal controls, previously depressed subjects showed relatively lower left frontal activation than right during baseline measurements, this finding was not replicated in a German study of currently depressed inpatients (Debener, Beauducel, Nessler, Brocke, Heilemann, & Kayser, 2000), even though EEG was measured twice.

To date, Hagemann et al. (1998) have conducted one of the more comprehensive examinations of the FBA model, and they came to the somewhat unsettling conclusion that "Depending on the particular analysis procedure, there were significant associations between anterior asymmetry and affectivity in line with the published findings, opponent to those findings, or no relation between anterior asymmetry and affective reactivity."

(pg. 372). These German researchers tried to closely follow Davidson's protocol, except they did not measure EEG twice. Davidson (1998) outlines other subtle, but potentially important inconsistencies.

Noting the lack of standardization among mood induction techniques, Hagemann et al (1998) chose to use pictures from the International Affective Picture System (IAPS; Lang, 1995) to induce emotion. The IAPS pictures have been standardized with normative data on subjective valence and arousal ratings, thus providing a relatively rigorous level of experimental control over the mood induction stimuli. The design was based on Davidson's first analytic strategy, in that EEG asymmetry was used to predict affective reaction in response to the pictures. Fifteen positive and 15 negative affect slides were used, and ratings (0-9) on eight emotion items (interest, happiness, amusement, pleasure, sadness, fear, anger, disgust) were obtained as the dependent variables.

As quoted above, the results depended on a few important methodological considerations and, overall, none of the hypotheses were strongly supported. In part due to the challenges of data collection and management, many asymmetry studies gather EEG data for brief periods only (e.g., between 1 and 2 minutes). Hagemann et al. compared the results of 30 second, 4 minute and 8 minute baseline measurement times. Each measurement was divided into half eyes-open, half eyes-closed segments. First, for the 30 second baseline recordings, only posterior asymmetry was correlated with affective reactions such that "Subjects with greater relative right parietal cortical activation reported more positive affect in response to positive slides and more negative affect in response to negative slides, compared with subjects with greater relative left-sided (parietal) activation" (pg. 381). Davidson (1998) has consistently found no relationship between parietal EEG asymmetry and affective reactivity, however others have argued that parietal cortex may be related to mood and emotional arousability (e.g., research cited above on emotion and parietal lobe functioning, see also Basso et al., 1996; Heller, 1990a,1990b).

When using the four and eight minute baseline data, EEG asymmetry in anterior-temporal regions was related to affect, but in the opposite direction that Davidson and colleagues would predict. Thus, subjects with relatively greater left-hemisphere anterior-temporal activation reacted more negatively to the negative slides and those with relatively greater right-hemisphere activation reacted more positively to the positive slides and less negatively to the negative slides.

Another important methodological feature of the Hagemann et al. (1998) study was the comparison of different reference approaches. Although EEG was measured with a monopolar montage referenced to Cz, there are statistical procedures that can "re-reference" the signals off-line to estimate a linked mastoids reference (see Tomarken et al., 1992). Comparison of these two analytic strategies revealed that they are not comparable, in that "only 7% of the variance of one of these asymmetric metrics can be predicted by the variance of the other" (pg. 383). Importantly, these authors clarify that a Cz reference should not truly be considered a monopolar reference, because *Cz is not an inactive site*. Thus, "it can be assumed that the electrical activity at the mastoids is considerably lower in magnitude than at the vertex (Cz), resulting in a more valid assessment of asymmetry, compared to the Cz montage" (p. 385). The attention to detail in this study is unsurpassed in many ways and the results provide important methodological information. However, as Davidson (1998) pointed out in a critique of this article, a number of factors may have contributed to the null findings, including a mixed-gender sample, lack of power, weak independent variable, inadequate assessment of emotional state and lack of two independent assessments of EEG asymmetry.

Emotion, Cognition and Frontal Lobe Functioning

Based on FBA theory, Bartolic et al. (1999) reasoned that relative hemispheric activation may correlate with improved lateralized cognitive task performance. Thus, if negative affect increases right frontal activation, then cognitive abilities mediated by the right frontal cortex should be enhanced. Conversely, if left frontal activation is associated with positive affect, then positive mood may enhance left frontal processing. To test this hypothesis, Bartolic et al. induced happy or sad moods in female college students and examined the effects on verbal and spatial fluency. There were four groups, Happy-Verbal, Happy-Spatial, Sad-Verbal, Sad-Spatial, with 15 subjects per group. These tasks were chosen as measures of left and right frontal lobe processing, respectively, based on research in normal and brain-damaged samples supporting their validity (Benton & Hamster, 1983; Ruff, 1988; Ruff, Allen, Farrow, Niemann, & Wylie, 1994).

The results fully supported the researchers' predictions. Participants in the Happy-Verbal condition showed increased verbal fluency and subjects in the Happy-Spatial group showed decreases in spatial fluency. In contrast, participants in the Sad-Verbal group showed decreases in verbal fluency and those in the Sad-Spatial group showed increases in spatial fluency. In their discussion, Bartolic et al. (1999) stated "to the best of our knowledge, this study is the first to demonstrate distinct effects of positive and negative emotional states upon cognitive functioning associated with the left and right frontal lobes" (pg. 680). As the authors note, however, the results provide only "indirect support for the inference that better figural than verbal fluency during a negative mood and better verbal than figural fluency during a positive mood is related to distinct patterns of frontal lobe arousal" (p. 681). The next logical empirical step to take is to conduct this study and include EEG asymmetry measures, which is exactly what was done in the present study.

Although well designed and producing positive results, a critical examination of Bartolic et al. (1999) suggests that there is a need for methodological improvement in a number of areas. Foremost among possible improvements concerns the mood induction procedure. Bartolic et al. (1999) used the Velten Mood Induction Procedure (VMIP; Velten, 1968) to induce happy and sad moods. The VMIP uses a series of 60 written and audiotaped statements that are read and listened to by the subjects. The self-statements start off neutral and progressively become more positive or negative, and the participant is asked to engage in the mood being targeted. Pre and post-test mood measures were obtained using the composite index of positive affect and sensation seeking (PASS) and the dysphoria composite scale (DYS) of the Multiple Affect Adjective Checklist-Revised (MAACL-R; Zuckerman, Lubin & Rincke, 1983).

According to two recent meta-analyses of the effectiveness of mood induction procedures (Gerrards-Hesse, Spies, & Hesse, 1994; Westermann, Spies, Stahl, & Hesse, 1996), the VMIP is not the most potent mood induction procedure. In fact, these reviews clearly suggest that using films to induce mood is more effective than most other methods. Positive mood is especially difficult to induce and, according to Westermann et al., compared to films or imaginary stories, "for the induction of positive mood states all other procedures proved to be considerably less effective" (pg. 572). Other methods include social interactions, facial expression and perception (e.g., viewing faces with different expressions), music, autobiographical writing and imagery, unexpected reinforcers, and negative/positive task performance feedback. Interestingly, effect sizes are routinely larger in non-college student populations and both articles note that concomitant measurement of physiological functions is rare, but necessary to include.

Although films seem to be the most potent laboratory mood inducers, one problem with using films is lack of standardization across studies. Most researchers develop their own films and procedures, which vary greatly in terms of description, length, content and emotional valence, not to mention their formal psychometric properties (if any). With the goal of producing a standardized set of film stimuli to evoke discrete primary emotions, Gross and Levenson (1995) collected data on over 70 films and winnowed the prime candidates down to 2 for each primary discrete emotion (disgust, sadness, fear, anger, amusement/happiness, surprise). They found that a Robin Williams comedy routine clip and a scene from the movie *When Harry Met Sally* most effectively induced discrete amusement and happiness. Sadness was best induced by a scene from *Bambi* and a scene from the movie *The Champ.* Overall, the films were more effective for inducing mood in women and in people who had seen the movie before. As will be described in the Methods section below, the Bambi film was chosen to induce a sad mood. The Robin Williams comedy routine was used in a pilot study in preparation for the present study. However, because a number of participants found the content of this film clip disagreeable and not humorous (e.g., discussion of alcohol and drug use), a different film clip was chosen for the present study. The film clip chosen was from a Bill Cosby comedy routine (see Methods).

Instead of using the MAACL-R, two other standardized and well-validated mood state measures were used in the present study: the Positive and Negative Affect Scale (PANAS; Watson, Clark & Casey, 1988) and the Pleasure-Arousal-Dominance (PAD) Emotion scale (Mehrabian, 1995a,b). The PANAS has been used by Davidson (Tomarken, Davidson, & Henriques, 1990; Tomarken et al., 1992a) in a few FBA studies, in keeping with the view of frontal asymmetry as it relates to positive affect/approach behavior and negative affect/avoidant behavior.

The Pleasure-Arousal-Dominance (PAD) Emotion scale has never been used in asymmetry research, but there are compelling reasons to use this measure in the present study. First, the PAD Emotion scale is unique in that it is less blatantly a measure of relatively simple emotions. This is due to its semantic differential format and larger variety of emotion words compared to the PANAS. Second, the PAD Emotion scales provide unique information. Mehrabian's PAD model of state emotion (and the associated model of temperament) has three orthogonal factors (Pleasure, Arousal, Dominance), in contrast to the two-factor model of the PANAS. Since Tomarken et al. (1992) found that the emotion dimension of pleasure-displeasure, which is what the Pleasure subscale of the PAD emotion scale is designed to measure, correlated with frontal EEG asymmetry, using such a scale appears warranted.

One aspect of the Bartolic et al. (1999) study that will remain unchanged in the present study are the dependent variables. The Controlled Oral Word Association Test (COWAT; Benton & Hamster, 1983) is a commonly used and well validated measure of verbal fluency and is sensitive to left hemisphere impairment, especially left frontal damage. The Ruff Figural Fluency Test (RFFT; Ruff, 1988) is also a well validated measure of spatial fluency. In a series of studies, Ruff (1988) demonstrated that the RFFT is especially sensitive to right frontal impairment compared to right posterior or left hemisphere damage. Both of these measures were utilized in the present study.

Emotion, Personality and Frontal Lobe Activation

Compared to emotion, the relationship between personality and EEG *asymmetry* has received less empirical attention. There are several reasons, however, to expect such associations. One reason is that Davidson's FBA model is meant to relate not only to emotion, but also approach and avoidant behavioral dispositions. This feature of FBA theory closely aligns it with the biosocial personality theories of Gray (1994) and Cloninger (1987).

In the only direct test of FBA theory as it relates to the personality dimensions of behavioral activation and behavioral inhibition (Gray, 1994), Sutton and Davidson (1997) examined the relationship between scores on the Behavioral Inhibition/Behavioral Activation Scales (BIS/BAS; Carver & White, 1994) and frontal EEG asymmetry. Using a sample of 46 participants with no history of psychiatric disorder, Sutton and Davidson found a strong correlation ($r$ = .53) between left frontal lobe activation and higher scores on a "BAS-BIS difference score," which was computed by subtracting the BIS score from the BAS score, thus providing a *relative* measure of behavioral activation. In addition, BAS scores taken alone were significantly correlated with left frontal activation ($r = .40, p < .01$) and the BIS scores taken alone were significantly correlated with right frontal relative activation ($r = .41, p < .01$). Interestingly, scores on measures of positive and negative affect were uncorrelated with frontal EEG asymmetry. These two studies clearly support the investigation of potential correlates between frontal EEG asymmetry and personality in the context of factor-based theories of personality, and suggest that personality variables may be more related to asymmetry than emotion variables, given that the correlations obtained in this study are among the strongest in the literature.

Even if FBA theory did not explicitly apply to Gray's model of personality, one would still expect some relationships between EEG asymmetry and personality. This is because the most common two-factor model of emotion used in EEG asymmetry research (the Positive and Negative Affect Scale) overlap considerably with the Eysenckian model of personality (Eysenck & Eysenck, 1993). With some qualifications, extraversion is usually correlated with positive affect and neuroticism is invariably correlated with negative affect. In fact, based on factor analytic work, Meyer and Schack (1989) argued that "the two-dimensional structure of mood-whether it is assessed as a state or a trait-and the two-dimensional structure of personality share a common core source of variation" (pg. 702). This conceptual overlap leads naturally to the question of how fundamental dimensions of personality relate to EEG asymmetry, and a brief review of relevant research is discussed below.

Consistent with predictions based on Eysenck's three factor theory of personality, a number of studies have found that extraverts have lower cortical arousal (Robinson, 1996; Tran, Craig, & McIsaac, 2001). However, evaluations of the Eysenckian, and other factor models of personality in the context of contemporary EEG asymmetry research is surprisingly sparse. The few studies that have been published have produced mixed results and are limited methodologically.

Hagemann, Naumann, Lurken, Becker, Maier, and Bartussek (1999) examinined the relationship between scores on the Eysenck Personality Questionnaire (EPQ; Eysenck & Eysenck, 1993) and asymmetry scores. Using a sample of 12 male and 24 female college students, the results of this experiment did not support the primary hypotheses. In fact, of the few significant results, the most important was directly contrary to FBA theory such that negative affect and neuroticism were associated with *greater* left frontal-temporal activation. Hagemann et al. (1999) also observed important gender differences. During baseline, females showed relatively less left-hemisphere alpha waves (greater activation) compared to men. This gender difference is consistent with other reports (Davidson, 1994), but the meaning of these differences is unclear.

Despite its numerous methodological strengths, the Hagemann et al. (1999) study is limited by low power. Because important gender differences were apparent in the EEG measures, the number of subjects available for an adequate test of the theory was not sufficient. Part of this study was intended to compare the classic four temperaments based on EPQ groupings (i.e., melancholic, choleric, sanguine, phlegmatic) across EEG measures. However, only five subjects were classified in the choleric group (high extraversion, high neuroticism) and only six subjects were classified in the phlegmatic group (low extraversion, low neuroticism).

Another recent study (Gale, Edwards, Morris, Moore & Forrester, 2001) examined the relationship between extraversion, neuroticism, cortical arousal and emotional reactivity in a sample of 30 female undergraduate students. EEG was recorded only during an emotion induction task. Participants were shown a series of 12 happy and 12 sad faces (equal number of male and female faces) on a computer screen and asked to mimic the facial expression as a means of inducing positive (happy) and negative (sad) moods. A single item mood check was used for each picture (rate 1-7 how 'happy' they felt during the facial expression). EEG was measured for the first 16 seconds of the 24 second stimulus display.

The most salient finding in this study was that extraverts showed significantly lower levels of cortical arousal than introverts at all recording sites, consistent with most of the prior research (Stelmack, 1990). Additionally, an important personality by emotion by hemisphere activation interaction was significant. Specifically, extraverts showed greater activation of the right frontal cortex during negative affect, but introverts did not. This finding suggests that the applicability of the FBA model may depend on other broad based personality dimensions, such as extraversion (see Reid, Duke & Allen, 1998). Unfortunately, this study is seriously limited by a number of factors, including the questionable nature of facial expression as a potent mood induction (Westermann et al., 1996), the use of a single-item mood state measure, and a relatively low number of subjects, which precludes a more powerful test of how EEG asymmetry, extraversion and neuroticism are related to changes in mood. In order to obtain a large enough sample to attempt comparisons among the four temperament types, as done by Hagemann et al. (1999), at least 60 subjects would be required. The present study will gather data from at least 60 subjects. Although methodologically demanding, there is reason to think that extraversion and neuroticism interact to predict affective *reactivity* (McFatter, 1994; Zelenski & Larsen 1999).

As noted above, Davidson (1994) suggested that more work needs to be done on "mapping" the personality correlates of EEG asymmetry. A few other studies have followed up on this recommendation. Tran et al. (2001) examined the relationship between personality and resting 8-13 Hz activity and found that extraverts showed greater alpha power in *all* frontal and central recording sites, but not parietal or occipital areas. Other personality dimensions also predicted cortical arousal. Higher scores on dominance, impulsivity and boldness traits were significantly associated with lower levels of cortical arousal (e.g., more alpha power). EEG asymmetry measures were not reported.

These results are consistent with the work of Robinson. David Robinson (1983, 1985, 1986a,b,c, 1989, 1996) has conducted some very sophisticated EEG/personality/intelligence research. A proper review of his work would require a 60-page paper in and of itself. Relevant to this research, however, he argued that:

> An introverted mental orientation will favor the learning of associations between discrete features of the external environment that are attended to selectively, in serial fashion, and in a way driven by ideation...In contrast, an extraverted mental orientation, due to low thalamocortical arousability and weak inhibition of brain stem reticular activating system, will favor the learning of associations among many parallel stimulus inputs (1996, pg. 77).

This description is conceptually congruent with Ivry and Robertson's perspective and other research suggesting that that the left-hemisphere is differentially involved in processing high-frequency information and ideation and the right-hemisphere is more involved in processing holistic and low-frequency information. Although relying to some extent on lateralization theory to account for individual differences in intelligence and personality (see Robinson, 1985, 1986c, 1989), Robinson's research has never utilized EEG asymmetry measures. His EEG recordings are complicated and based on changes in alpha waves in response to photic stimulation (i.e., flashing lights) using only a Cz lead with a linked mastoid ground. Perhaps because this procedure can induce symptoms of distress and even seizures (Ulett, Gleser, Winokur, & Lawler, 1953), it is not surprising that this method is not used very often.

## Summary and Hypotheses

Although the theoretical and empirical basis of this dissertation stems from a variety of sources, each area concerns the potential relationship between asymmetric cortical functioning in posterior and anterior cortex and specific individual difference variables. Martindale's (1991) theory of mind provides an empirically supported and heuristic theoretical foundation for investigating the neural correlates of psychological processes. The work of Ivry and Robertson (1999), Davidson (1998) and many others contributes important information that contributes to Martindale's perspective.

Although there are limitations in the use of EEG data as an index of brain functioning, a solid foundation of prior research justifies focusing on how asymmetrical cerebral activation relates to cognition, emotion, personality and creativity. Many of these studies, however, have serious methodological limitations, including low power, single-method assessment of emotion, personality and/or creativity, and limitations in EEG measurement. The design of this dissertation is intended to improve upon these limitations by using a rigorous experimental procedure.

### Hierarchical Visual Analysis, Emotion, Personality and EEG Asymmetry

What is the relationship between performance on a Global-Local task and Rorschach location scores? Based on the literature reviewed above, it was predicted that Whole and Minor Detail Rorschach location responses will correlate with *local* responses on the Global-Local task and Major Detail Rorschach location responses will correlate positively with global responses on the Global-Local task. In addition, because individual Rorschach inkblots vary with respect to the extent that they "pull" for different location responses, the relationship between Global-Local task performance and Rorschach location responses will be examined for subsets of the inkblots that are distinguished on the basis of whether or not they tend to elicit Whole or Detail responses. The prediction here is that Whole responses to the more discretely structured inkblots require more integration of local elements and therefore local processing on the Global-Local task will be associated with Whole responses on these blots specifically.

What is the relationship between hierarchical visual processing and mood? Based on Basso et al. (1996) and Double Filtering by Frequency (DFF) theory it is predicted that mood (depression and anxiety) measures will correlate with hierarchical visual analysis on the Global-Local task and the Rorschach such that greater negative mood will predict local processing and vice versa.

What is the relationship between hierarchical visual analysis and personality? It is predicted that performance on the global-local task and the Rorschach location scores will correlate negatively with (a) introversion and (b) neuroticism and positively with (a) extraversion, (b) optimism and (c) Mehrabian's Globality-Differentiation Scale (Mehrabian et al., 1997).

What is the relationship between baseline parietal EEG asymmetry and hierarchical visual processing? Based on DFF theory it is predicted that baseline parietal EEG asymmetry will correlate with hierarchical visual analysis such that relatively greater left hemisphere activation will be positively correlated with local visual processing. The Global-Local task and the Rorschach were used to quantify hierarchical visual analysis.

Creativity, Primary Process Cognition, and EEG Asymmetry

What is the relationship between primary process cognition and EEG asymmetry during baseline and creative task performance? Baseline EEG asymmetry will correlate with primary process content on the Rorschach such that greater primary process content responses will be evident in those with greater relative activation of the right hemisphere. Primary process cognition will also correlate with relatively greater right hemisphere activation during creative task performance. The Rorschach was used as an analogue creative task and EEG was measured while subjects were constructing their responses to the Rorschach stimuli. Anterior and posterior EEG asymmetry was examined to determine if the predicted relations between EEG asymmetry and primary process are specific to either cortical sectors.

What is the relationship between measures of creativity and EEG asymmetry during creative task performance and baseline EEG asymmetry? Creative potential was operationalized in four ways: using a composite creative potential score that combines scores on the Remote Associates Test, the Alternate Uses Test, and the Adjective Checklist; using the Cognitive Disinhibition Scale; using Primary Process scores quantified from the Rorschach responses; and using Eysenck's Psychoticism scale. It was predicted that subjects demonstrating greater creative potential would show greater relative activation of the right hemisphere during creative task performance (constructing Rorschach responses) than less-creative subjects. Given the conflicting previous findings regarding the relationship between resting EEG asymmetry and creative potential, no specific predictions concerning these relationships were made.

What is the relationship between paper-and-pencil measures of creativity and Rorschach primary process content? Correlations between these measures were conducted, the prediction being that subjects who score higher on the paper-and-pencil measures of creativity will show higher levels of primary process content in their Rorschach responses.

Emotion, Cognition, Personality, and EEG Asymmetry

What is the relationship between baseline EEG asymmetry and emotion and personality variables? In an attempt to replicate Sutton and Davidson's (1997) findings, baseline EEG asymmetry in frontal regions will correlate with the Behavioral Inhibition/Behavioral Activation Scales such that greater left frontal asymmetry will correlate positively with the BAS scale and greater right frontal asymmetry will correlate positively with the BIS scale. Relatively greater left frontal activation will also correlate positively with trait pleasure, dominance, and positive affect. The relationship between parietal and central EEG asymmetry will also be examined with the prediction that asymmetry at these sites will not correlate with personality or emotion variables.

What is the effect of happy and sad moods on verbal and spatial fluency? Happy and sad mood induction will influence cognitive functioning such that happy moods will facilitate verbal fluency and decrease figural fluency and sad moods will increase figural fluency and decrease verbal fluency.

What is the effect of happy and sad moods on frontal EEG asymmetry? Happy and sad mood induction will cause changes in EEG asymmetry (compared to pre-mood asymmetry) such that happy mood induction will cause shifts toward greater left-hemisphere activation and sad moods will cause shifts toward greater right-hemisphere activation, regardless of cognitive task completed (verbal or figural fluency).

# CHAPTER 2: METHOD

## Participants

Seventy right-handed participants (28 males, 42 females) were recruited from the Psychology Subject Pool at the University of Maine. The average age was 19.8 years (*SD* = 1.7). Participants were awarded extra credit toward their psychology course final grade and informed consent was obtained from all participants (see Appendix A). Two participants were eliminated from the sample because they failed to complete portions of both of the two testing sessions (see Procedure below and Appendix B for a description of the testing session format). Eleven subjects failed to complete the EEG component of session two. Thus, the final sample used for data analyses included sixty-eight participants (27 males, 41 females) who completed all of session one and the first half of session two and fifty-seven participants (24 males, 33 females) who completed both session one and session two.

## Measures

The measures used in this study fall into five categories: creativity measures, measures of emotion and mood, personality measures, experimental tasks, and EEG measurement. Each category will be described in more detail in the following paragraphs.

### Creativity Measures

The Alternate Uses Test (AUT; Appendix C) is a commonly used measure of ideational fluency and has been used extensively in studies of creativity (Wallach & Kogan, 1965). According to Guilford (1950), ideational fluency is one of the critical components of creativity. The AUT requires the respondent to write as many different uses as they can think of for three ordinary objects (i.e., shoe, brick, newspaper). Three minutes are given for each object. Validity of the AUT as a measure of creativity has been demonstrated by showing that performance on this task does not correlate significantly with measures of intelligence (Vartanian, 2002) but does correlate with other measures of creativity (Wallach & Kogan, 1965). The AUT was scored by adding the total number of uses written for each of the three objects. The average total AUT score for the present sample was 29.6 (*SD* = 11.37). For the present sample, the Coefficient Alpha for the AUT was .84.

The Remote Associates Test (RAT; Appendix D) is a measure of how well a person can make unusual (i.e., remote) associations. Mednick (1962) developed the measure and a revised version with updated norms (see Appendix E) was used in this study. On this test, participants are presented with three words and are instructed to generate a fourth word that is common to all three. For example, the word that is common to "poke", "go", and "molasses" is "slow." There are thirty items on the RAT and the score is calculated by adding up all of the correct responses given by the participant. The average score on the RAT in the present sample was 8.54 (*SD* = 3.73). Preliminary results using the revised version of the RAT show adequate split-half reliability ($r$ = .84). In contrast to the ideational fluency concept measured by the AUT, the RAT is meant to tap into the extent to which a person has broad associative hierarchies, a skill central to Martindale's (1995) theory of creativity. Supporting the validity of the RAT, Mednick (1962) showed that the original RAT correlated significantly with expert ratings of real-life creativity in architects. Vartanian (2002) recently showed that the revised RAT correlates moderately ($r$ = .26) with Full Scale IQ using an abbreviated scale of intelligence (Wechsler, 1999). This finding is not unexpected, given that creativity and IQ are expected to correlate with one another in the general population, but only up to an IQ score of about 120 (Martindale, 1991).

The Creative Personality Scale (CPS; Gough, 1979; Appendix F) is a 30-item adjective checklist that differentiates high and low creative individuals. Eighteen of the items are characteristic of highly creative people and 12 items are characteristic of those with lower creative abilities. The overall score on the CPS is calculated by subtracting the sum of the low-creative characteristics from the sum of the high-creative characteristics. The average score on the CPS in the present study was 4.87 ($SD$ = 3.7). Adequate levels of internal consistency have been reported ($r$ =.77 for males, .81 for females) and the CPS predicted independent ratings of creative ability better than other adjective checklists of creative personality features (Gough, 1979).

In the present study, the RAT did not correlate significantly with the AUT or the CPS. The AUT and CPS were moderately correlated ($r = .26, p < .05$). This pattern of correlations is almost identical to those recently reported by Kwiatkowski (2002). Because the three measures of creativity described above each measure somewhat distinct components of creative potential, previous research (Kwiatkowski, Vartanian, & Martindale, 1999) has used a linear combination of these three scales to construct a composite measure of creative potential. This approach was used in the present study. Specifically, total scores on the AUT, RAT, and CPS were standardized and then summed to compute a measure referred to hereafter as the "composite" measure of creative potential.

The Cognitive Disinhibition Scale (CDS: Vartanian & Martindale, 2001; Appendix G) is an 18-item questionnaire developed as a self-report measure of cognition theoretically linked to creativity. The CDS is a two-factor scale that assesses cognitive immersion and flexibility. Each item is rated on a scale ranging from -3 to +3. The average score on the CDS in the present sample was 18.10 ($SD = 11.10$). The Coefficient Alpha for the CDS in the present study was .73, which is consistent with previous research (Vartanian & Martindale, 2001).

The Regressive Imagery Dictionary (Martindale, 1990) was used to analyze participants' Rorschach inkblot responses for elements of primary and secondary process cognition. The RID is a computerized text analysis program that analyzes the occurrence of 2,900 specific words. The validity of the RID has been demonstrated in numerous studies (Martindale, 1990). Percentage scores for total primary process, total secondary process, and a composite primary process score (i.e., primary process minus secondary process) were calculated. Percentage of primary and secondary process content was calculated to control for differences in total word productivity in Rorschach responses.

In the present study, preliminary analyses suggested that the RID needed to be modified slightly for use with Rorschach responses. Specifically, two content categories were overly represented in the Rorschach responses. These were the category for Vision and the category for Narcissism. Both of these categories are subscales of the overall Primary Process scale. The reason these two categories were over-represented in Rorschach responses was due to the fact that the word "Look" is used quite often when people provide Rorschach responses (i.e., "It looks like a bat."). The Narcissism category was over-represented because it contains references to body parts (i.e., head, face, arm, leg, body). Words in this category are extremely common in Rorschach responses because the description of the human and animal figures seen in the blots often involves elaborating on where the body parts are located (e.g., "This looks like a person, here are the arms, legs, body, feet and the head is up here).

Because these two categories were over-represented in the Rorschach responses and appeared to overestimate the true levels of primary process cognition in the text, these two categories were excluded from the overall Primary Process scale. With the categories included, seventeen percent of the text was categorized as primary process. With these two categories removed, nine percent of the text was categorized as primary process. The latter percentage is more consistent with previous research (Martindale, Covello & West, 1986; Martindale & Dailey, 1996; West & Martindale, 1988). The correlation between the original Primary Process percentage scores (i.e., Narcissism and Vision categories included) and the revised Primary Process percentage scores (i.e., Narcissism and Vision categories excluded) was .97. No significant gender differences were evident on either Primary Process score or on the Secondary Process score.

Emotion Measures

Five measures of emotion and mood were used in the present study. The Beck Depression Inventory-II (BDI-II; Beck, 1985) is a 21-item measure of depressive symptoms and distress with well established reliability and validity (Beck, 1985). The Coefficient Alpha of the BDI-II in the present sample was .90. The Trait Anxiety scale of the State-Trait Anxiety Inventory (STAI-T; Spielberger, 1977) is a 20-item measure of trait anxiety with well established reliability as well as validity as a measure of trait anxiety. The Coefficient Alpha of the STAI-T in the present study was .90. The Life

Orientation Test (LOT; Appendix H) is a 14-item measure of optimism and pessimism with adequate internal consistency and convergent validity (Marshall, Wortman, Kusulas, Hervig, & Vickers, 1992). The following three scores are produced from this measure: total optimism, total pessimism and a composite score (i.e., total optimism minus total pessimism). The Coefficient Alpha for the positive subscale of the LOT in the present study was .82. The Coefficient Alpha for the negative subscale of the LOT in the present study was .86.

Mehrabian's (1995a) scale of his three-factor Pleasure, Arousal, Dominance (PAD) model of emotion was also administered. Based on Osgood's (Osgood, Suci, & Tannenbaum, 1957) extensive work on the principal components of meaning, Mehrabian developed the PAD Emotion scale to assess emotional states that correspond to the meaning factors of Evaluation, Activity, and Potency. The PAD Emotion scale is a 34-item, semantic differential format questionnaire in which the respondent chooses one of two contrasting emotion words and rates how strongly one of the emotions is "usually" felt in comparison to the other emotion word. The PAD is also available in an eight-item short form that can be used to measure emotional *states*, rather than traits. The short form was used to assess pre- and post-mood in the mood induction component of the study.

The PAD Emotion scale has undergone extensive psychometric evaluation. In a series of three studies, Mehrabian (1995a) showed that the three subscales (i.e., Pleasure, Arousal, Dominance) of the PAD Emotion scale accounts for the majority of variance in 42 different measures of emotion and displays discriminant and predictive validity in a wide variety of experimental contexts. The Coefficient Alpha for the PAD Pleasure emotion scale in the present study was .88. The Coefficient Alpha for the PAD Arousal emotion scale was .83. The Coefficient Alpha for the PAD Dominance emotion scale in the present study was .87.

The Positive and Negative Affect Scale (PANAS; Appendix I) is one of the most commonly used measures of the "two factor" model of emotion (Watson, Clark & Carey, 1988). The PANAS is a 20-item questionnaire that asks the respondent to rate the extent to which they experience a particular emotional state (e.g., determined, irritable, alert). The PANAS was administered as a trait measure (i.e., how you usually feel) and a short form of the PANAS (Appendix J) was used as a measure of pre- and post-mood induction emotional state in the present study. The PANAS has undergone extensive psychometric evaluation and has shown to be a reliable and valid measure of trait positive and negative emotion (Watson et al., 1988). The Coefficient Alpha for the positive affect scale of the PANAS in the present study was .66. The Coefficient Alpha for the negative affect scale of the PANAS in the present study was .76.

<u>Personality Measures</u>

Five personality measures were used in this study. The Eysenck Personality Questionnaire-Revised (EPQ-R; Eysenck & Eysenck, 1993) is a thoroughly researched measure of Eysenck's three-factor model of personality, which includes Extraversion (E), Neuroticism (N), Psychoticism (P) and Lie (L) scales. The extraversion scale measures behavioral and cognitive traits meant to distinguish between those who prefer and engage in social activities versus those who do not (i.e., introverts). The Coefficient Alpha for the Extraversion scale in the present study was .86. The Neuroticism scale measures individual differences in emotional stability and reactivity. The Coefficient Alpha for the

Neuroticism scale in the present study was .88. Higher scores on the Psychoticism scale suggest tendencies toward aggressiveness, egocentricity, impulsivity, creativity, and low empathic capacity. The Coefficient Alpha for the Psychoticism scale in the present study was .84. The Lie scale measures individual differences in the extent to which persons portray themselves in a favorable light by denying faults common in most people. The Coefficient Alpha for the Lie scale in the present study was .89. The EPQ-R has been shown to be reliable, and is one of the most widely used measures of a factor-based theory of personality (Eysenck & Eysenck, 1993).

The Pleasure, Arousal, Dominance (PAD) Temperament scales (distinct from the above-mentioned PAD Emotion scales) are a set of *three* questionnaires that assess Mehrabian's (1996b) three-factor model of temperament. As with the PAD Emotion scale, Mehrabian developed the PAD Temperament scale based on Osgood's (Osgood et al., 1957) three-factor theory of meaning. In contrast to the PAD Emotion scale, the PAD Temperament scales are meant to assess individual differences in behavioral, cognitive and emotional *traits*. The Pleasure-Displeasure questionnaire is a 43-item semantic differential scale and parallels Osgood's Evaluation factor. The respondent is asked to indicate the extent to which they experience the balance between two emotions. The Coefficient Alpha for the Pleasure-Displeasure temperament scale in the present study was .84. The Arousal scale of the PAD Temperament scales is a 34-item scale that assesses individual differences in responsiveness to arousing situations. The scale asks for a rating (-4 = very strong disagreement to +4 = very strong agreement) for each descriptive statement. The Arousal scale parallels Osgood's concept of Activity. The Coefficient Alpha for the Arousal temperament scale in the present study was .89.

The PAD Dominance temperament scale, similar to the Arousal temperament scale, asks for ratings of agreement/disagreement with each descriptive statement. The Dominance temperament scale assesses individual differences in the tendency to behave and think in domineering or powerful ways and is conceptually akin to Osgood's concept of Potency. The Coefficient Alpha for the Dominance temperament scale in the present study was .87. Each subscale provides a summary score for the traits of pleasure, arousal, and dominance. The PAD Temperament scales have undergone extensive development and psychometric refinement and show good internal consistency and excellent construct validity (see Mehrabian, 1996b).

The Tridimensional Personality Questionnaire (TPQ) is a 98-item questionnaire developed by Cloninger to measure his three-factor model of personality (Cloninger, Przybeck, Svrakic, & Wetzel, 1994). Cloninger proposes Novelty Seeking (NS), Harm Avoidance (HA) and Reward Dependence (RD) as the three basic independent factors of temperament. Each relatively orthogonal factor is linked to the functioning of a specific group of monoamines (dopamine, serotonin and norepinephrine, respectively) and responsiveness to reward and punishment. The TPQ has undergone extensive psychometric evaluation and demonstrates acceptable reliability and validity (Cloninger et al., 1994). The Coefficient Alphas for the NS, HA, and RD scales in the present study were .88, .89, and .86, respectively.

The Behavioral Inhibition/Behavioral Activation Scales (BIS/BAS; Appendix K) were developed to assess Gray's (1994) two-factor model of personality and show adequate levels of reliability and validity (Carver & White, 1994). The BIS is a single scale and the BAS scale comprises three subscales, referred to as Drive, Reward

Responsiveness, and Fun. An average score of the three subscales is also computed and referred to as BAS Average.

Based on Werner's (1957) and Piaget's (1960) theories of mental development, Mehrabian (Mehrabian, Stefl, & Mullen, 1997) developed the Globality-Differentiation Scale (GDS; Appendix L) as a measure of individual differences in what he terms "adult emotional thinking" (Mehrabian et al., 1997, pg. 326). This scale measures the extent to which thought processes are differentiated versus undifferentiated. Undifferentiated cognition represents a lower level of cognitive development, wherein various features of experience are fused (e.g., emotion and cognition, reality and fantasy, and self versus other). Mehrabian et al. have shown that the GDS correlates with neuroticism and trait anxiety and that the scale measures individual differences in the extent to which emotions, wishes and fantasies influence thought processes. The Coefficient Alpha for the GDS in the present study was .69.

Experimental Tasks

The Global-Local task is a series of 16 images presented on a computer screen. Each image has a top figure and two bottom figures (see Appendix M). The respondent is asked to "quickly associate the top figure with one of the bottom figures." One of the bottom figures matches the local (i.e., detail) features of the top figure and the other bottom figure matches the top figure based on the global (i.e., overall) features of the top figure. The two figures in Appendix M help illustrate the nature of this task. The first figure in Appendix M shows a global-match on the bottom left and a local match on the bottom right. The second figure in Appendix M shows a global match on the bottom right and a local match on the bottom left.

The 16 stimuli can be divided into *four subgroups* that differ in terms of how many elements make up the geometric figures (i.e., 3/4, 5/6, 9/10, and 15/16). For example, the first example in Appendix M has three elements for the bottom local match and four elements in the bottom global match and top figure. The second example in Appendix M has 15 elements in the local match and 16 elements in the global match and the top figure. To prevent biased responding, the position (e.g., right or left side) of the local and global matching figures on the bottom is equal within the four subgroups of figures. That is, there are two local matching figures on the right and two matching local figures on the left.

The answer sheet used in the present study for the Global-Local task is shown in Appendix N. The person is instructed to mark the X on the left if they associate the bottom figure on the left with the top figure and vice versa. The global-local task takes approximately one minute to complete. Basso, et al. (1996) reported acceptable levels of internal consistency ($r = .76$) for an 8-item global-local task and excellent internal consistency for a 32-item global-local task ($r = .93$). Higher scores on the Global-Local task indicate greater global responses.

Six of the ten Rorschach inkblots were used in the present study. Cards I, II, III, IV, VIII, and X were chosen. Appendix O provides a reduced size, achromatic reproduction of the six blots used in this study. These blots were chosen to represent three levels of overall composition. Cards I and IV are relatively unified cards that are associated with Whole responses normatively. The gestalts of cards III and X are relatively broken and typically pull for Detail responses as opposed to Whole responses. Cards II and VIII fall in between the other cards in terms of their overall gestalt and are equally likely to elicit a Whole response or a Detail response (Phillips & Smith, 1953). The location scoring used in the present study relied on the norms used in Exner's Comprehensive System (1992).

The data from this study support these distinctions based on the percentage of Whole, Major Detail, and Minor Detail responses given to each card. The percentages of Whole responses for each card were as follows: Card I = 67%, Card II = 40%, Card III = 14%, Card IV = 63%, Card VIII = 33%, Card X = 30%. The percentage of Major Detail responses for each card were as follows: Card I 18%, Card II 49%, Card III 63%, Card IV 26%, Card VIII 55%, Card X 60%. The percentage of the Minor Detail responses per card was: Card I 15%, Card II = 12%, Card III = 24%, Card IV = 12%, Card VIII = 13%, and Card X = 11%. Thus, Cards I and IV showed the highest proportion of Whole Responses. Cards III and X showed the highest proportion of Detail responses. Minor detail responses were equally present in all cards except Card III, which showed the highest proportion of Minor Detail responses among the six inkblots.

The blots were displayed on a stand 30 cm from the participant's face. For each card, participants were asked to construct three responses to the question "What might this be?" and were instructed to "*Be creative in your responses.*" After viewing each image for 45 seconds, participants verbalized their three responses. The experimenter wrote down what they said verbatim and recorded the responses on a tape recorder. Immediately after giving each response, participants were asked follow-up questions to clarify their responses. Tape-recorded responses were transcribed verbatim and analyzed using the RID.

Two film clips were chosen for the mood induction procedure. Bambi was chosen to induce a sad mood because previous research found support for its effectiveness in inducing discrete sadness (Gross & Levenson, 1995). The film clip used from Bambi initially depicts a nurturing interaction between Bambi and his mother, followed by the scene in which Bambi's mother is shot by a hunter and Bambi is shown feeling sad. The film clip began at minute 46:25 and ended at 51:33. Therefore, the clip from Bambi lasted five minutes and eight seconds.

A scene from a Bill Cosby stand-up comedy routine from the film Himself was chosen to induce a happy mood. During this film clip, Bill Cosby was alone on a stage telling jokes about the behavior of his children and the nature of marriage. The film clip used in the present study was constructed from two scenes from the film that were edited to coincide with one another so that they appeared to be one complete scene. The first clip began at minute 26:30 and ended at 28:41. The second clip began at minute 48:25 and ended at minute 52:37. Therefore, the entire length of this film clip lasted six minutes and thirty-three seconds.

Verbal (i.e., phonemic) fluency was measured using the Controlled Oral Word Association Test (COWAT; Benton & Hamster, 1983). The COWAT is a commonly used measure of phonemic fluency and is sensitive to left-frontal lobe damage (Benton & Hamster, 1983). The respondent is asked to say as many words as they can think that begin with a specific letter (i.e., C, F, and L) during a one-minute period. Following the procedure used by Bartolic et al., (1999), instead of verbalizing the words, participants in this study were asked to write them down. See Appendix P for the response sheet used in this study. Also following the procedure used by Bartolic et al., an average of the first two letters was used as the pre-mood induction measure of verbal fluency and the total number of words written for the last letter (i.e., L) was used as the post-mood induction measure of verbal fluency.

Spatial fluency was measured using the Ruff Figural Fluency Test (RFFT; Ruff, 1998). Three of the five Ruff Figural Fluency Task forms were used, following Bartolic, et al. (1999) (see Appendix Q for an example of items from form 1). For this measure, each form contains five columns and seven rows of boxes that cover an entire 81/2 by 11 inch page. Each box contains a pattern of dots. The respondent is asked to "make as many unique figures as you can by connecting three or more dots together using straight lines." Performance was scored for the total number of non-perseverative (i.e., repeated) designs. Again, following the procedure used by Bartolic et al., the average of the first two forms was used as the pre-mood induction measure of spatial fluency and the total score on the third form was used as the post-mood induction measure of spatial fluency.

EEG Measurement

EEG was recorded from 6 sites comprising midfrontal (F3-F4), central (C3-C4), and parietal (P3-P4) regions. (Odd numbered electrode sites denote the left side). To record eye muscle movements (to detect potential artifact), one electrode was placed just below one eye and one electrode was placed laterally to one eye. The side of the face for placement of these electrodes was randomly determined. All electrodes were referenced to a linked mastoid ground (Pivik et al., 1993).

Several steps were taken to ensure proper application of EEG electrodes and this procedure was conducted by the first author and trained lab assistants with extensive prior experience. First, the proper locations were determined using the 10-20

International System. Following the scalp measurements, each site was prepared for electrode placement. This was done by gently scrubbing the area with rubbing alcohol and with an electrode preparatory paste (*Nuprep*). Each electrode was then applied to the scalp using a saline conductive paste (Ten20). Based on previous experience, very few (if any) subjects find this process uncomfortable. All electrode resistances were below 5k ohms, which is the minimal level that is required for proper brainwave measurement (Pivnik, et al., 1993).

EEG was measured using a Grass Model 89 eight-channel electroencephalograph, a Toshiba Equium7000s personal computer, and a Keithley DAS1202 Analog-to-Digital (A/D) conversion card to allow digital recording and analysis of the analog EEG signal. This A/D digital conversion card will allow up to 50k samples/sec over the total number of channels. All A/D conversion occurred at 200 Hz, which is twice the highest expected frequency of eye muscle movement. The signal was transmitted from the EEG to the A/D card through eight shielded wires, one for each channel. These were single-ended inputs, all referenced to a common ground. Sensitivity and all filters were controlled through a master switch on the EEG. Sensitivity was set to 7uV/MM. Low bandpass filter was set to 1Hz. High bandpass filter was set to 70Hz. The 60Hz notch filter was set to eliminate common electrical interference.

Artifact is always present in EEG recordings (Pivik et al., 1993), and visual inspection of the raw data is required to eliminate epochs (e.g., sections) that are contaminated by excessive eye movement or scalp muscle movement. All EEG recordings were visually inspected using Acq*Knowledge* (Version 3.2.4), a windows based software program that enables the visual inspection of eight channels of EEG recordings. Artifacts due to excessive muscle movement (e.g., eye blinks, scalp muscle movement, eye movement) were deleted. Artifact was defined by the presence of obvious distortions of the normal EEG signal in the eye or scalp electrode leads. Consistent with previous research (e.g., Tomarken et al., 1990; Tomarken et al., 1992), if artifact was present in any one channel, EEG from all channels during that time period was removed. This procedure for artifact removal is consistent with previous EEG asymmetry research (Davidson et al., 1979; Davidson, 1988; Davidson & Fox, 1989; Tomarken et al., 1990; Tomarken et al., 1992).

The average number of artifact free epochs was similar across all eyes-closed recording periods (i.e., session one baseline $M = 36.53$, $SD = 9.04$, session two pre-mood induction $M = 37.12$, $SD = 7.38$, session two post-mood induction $M = 35.46$, $SD = 8.43$). In the present study, an epoch was 2.56 seconds in length. Thus, an average of 93, 95, and 90 seconds of artifact free EEG epochs were analyzed for session one, pre-mood induction, and post-mood induction recording periods, respectively. The total number of possible epochs during each baseline eyes closed recording period was 46 (i.e., 120 seconds divided by 2.56 second epoch lengths).

The average number of artifact-free epochs for the EEG data obtained while participants constructed their Rorschach responses was somewhat higher ($M = 51.22$, $SD = 21.64$). On average, 131 seconds of artifact free EEG was available to calculate EEG power during the Rorschach task. Even though six minutes of EEG was recorded across the six inkblots (45 seconds each), the EEG was much more contaminated by artifact because the participants had their eyes open, which resulted in more artifact due to eye blinks and muscle movement. The total number of possible epochs during the creative task was 105 (i.e., 270 seconds divided by 2.56). There were no gender differences evident for the average number of artifact-free epochs for any of the eyes-closed recordings or for the EEG recorded during the Rorschach task.

To calculate EEG power values, all artifact-free epochs of 2.56 seconds in duration for each electrode site (F3, F4, C3, C4, P3, P4) were subjected to a Fast Fourier Transform (FFT) using a Hamming window (Ray, 1990). As outlined in the introduction, the FFT decomposes a complex waveform into its constituent sine wave components and provides estimates for the prevalence of various frequencies present in the raw EEG signal. These estimates are referred to as power. The SAS computer software (Version 8.02, 2001) was used to calculate EEG power using the SPECTRA procedure. The results of the SPECTRA procedure were output to an Excel file that was formatted to calculate the average power values for each frequency band and each recording site across all artifact-free epochs.

Next, *power density* was calculated for each electrode site and each frequency band (Delta = 1-3 Hz, Theta = 4-7 Hz, Alpha = 8-13 Hz, Beta1 = 14-20 Hz, Beta2 = 21-30 Hz). Power density is defined as the average power within a frequency band. It is computed by *dividing the total power within each frequency band by the number of individual frequencies within each frequency band* (see Davidson, 1988; Davidson et al., 2000). Therefore, the power density values for each band were calculated as follows: total spectral power for Delta (1-3 Hz)/4, total spectral power for Theta (4-7 Hz)/4, total spectral power for Alpha (8-13 Hz)/6, total spectral power for Beta1 (14-20 Hz)/7, total spectral power for Beta2 (21-30 Hz)/10. Power density (i.e., average power within each frequency band) was used instead of raw spectral density because the majority of recent research on EEG asymmetry has used power density rather than raw spectral power (see Davidson et al., 1990; Davidson et al., 1995; Davidson, et al., 1999; Davidson et al., 2000; Debener et al., 2000; Kang et al., 1991; Papousek & Shulter, 1998; Sutton & Davidson, 1997; Tomarken et al., 1990; Tomarken et al., 1992).

Spectral power values are always positively skewed, whether using raw power or power density calculations. According to Gasser, Bacher and Mocks (1982):

> One drawback of these parameters (spectral power) is that their empirical distribution does not follow the normal distribution in samples of healthy individuals. These deviations are usually rather gross, resulting both from asymmetry and long tails of the empirical distribution. As a consequence, a great number of statistical techniques, which rely on the normal distribution, cannot be used. (pg. 119).

In order to normalize the distributions of the power density values, a natural log transformation was applied (Davidson, 1995; Tabachnick & Fidell, 2001). In the present study, because power density estimates were below a value of 1, the natural log transformation results in a negative number (see Davidson et al., 2000).

EEG asymmetry values were calculated by subtracting the natural log transformed power density estimates of the left lead from the natural log transformed power density estimates of the right lead (i.e., Log Right - Log Left). Therefore, *higher scores on asymmetry measures indicate relatively greater left hemisphere activation.*

As described above, the EEG recordings during the Rorschach task were obtained in six segments (one for each inkblot) lasting 45 seconds each. The power calculations described above were completed for each of the six segments and, to obtain an overall estimate of power values during the Rorschach task, an average of the log power values was calculated across the six recording periods using the procedures described above.

The temporal stability of EEG asymmetry was computed in a manner consistent with prior research (Tomarken et al., 1992). First, the asymmetry scores from the initial baseline EEG recordings from session one and session two for each band were standardized. Stable EEG asymmetry was defined as any subject whose standardized asymmetry score at session two was within .3 standard deviations of their session one standardized EEG asymmetry score. In addition, a "relaxed" .5 standard deviation criterion was also used to increase the number of subjects in the stable group. Temporal stability was calculated for each band separately because different frequency bands can show different levels of temporal stability (see Tomarken et al., 1992). Alpha and Theta frequency bands are generally more stable, followed by Delta, Beta 1, and Beta 2 (Tomarken et al., 1992).

## Procedure

The experiment was conducted in two, two-hour sessions, separated by two to three weeks. See Appendix B for an overview of the sequence and timeline for each session.

### Session One

During session one, participants first were oriented to the laboratory and completed the informed consent form. Next, participants completed the Alternate Uses Test and the Remote Associates Test (randomly ordered). Then, participants completed a packet of emotion-related questionnaires and two creativity measures, including the Beck Depression Inventory-II, State-Trait Anxiety Inventory - Trait scale, Pleasure, Arousal, Dominance (PAD) Emotion Scale, Positive and Negative Affect Scale, Life Orientation Test, Creative Personality Scale, and Cognitive Disinhibition Scale. These questionnaires were placed in a randomized order. After these measures were completed, the EEG component of session one was administered.

During the EEG component of each session, the participant sat reclined in an overstuffed chair in a small room adjacent the experimenter's room, which housed the EEG equipment and computer to control the stimuli presentations. Both EEG sessions began in the same manner. Two minutes of EEG was recorded with the participant sitting relaxed with their eyes closed. Following initial EEG baseline measurement, each participant completed a series of tasks.

After the initial baseline EEG recording in session one, participants next completed the Global-Local task. The Global-Local task was presented on a computer screen 60 cm from view at eye-level. Participants marked their responses on an answer sheet (see Appendix N), which was on a "lap-desk" placed in a comfortable position to write. The instructions for the global-local task were: "I am going to show you a series of images on the computer screen. Each image is structured in the same way. There is one geometric figure on the top and two geometric figures on the bottom. What I would like you to do is quickly associate one of the bottom figures with the top figure. Choose whichever bottom figure you think goes best with or is most closely associated with the top figure. If you think the bottom figure on the right is most closely associated with or goes best with the top figure, circle the X on the right for that item on the answer sheet. If you think the bottom figure on the left goes best with or is most closely associated with the top figure, circle the X on the left for that item on the answer sheet. Do you have any questions?" The Global-Local task took approximately one minute to administer. Only one participant lost track of the items during the task. For this person, the task was readministered. To score the Global-Local task, any global response was scored as a 1 and any local response was scored as a 0. Therefore, higher scores on this task indicated more global responses. The scores on the Global-Local task were arcsin transformed, following the approach used by Basso et al. (1996) because the distribution of scores on this task were negatively skewed.

After the Global-Local task was completed, the Rorschach was administered. As mentioned above, six of the 10 blots were used (Cards I, II, III, IV, VIII and X). For every participant, the blots were presented in the same order (I, II, III, IV, VIII, and X). The blots were placed on a stand 30 cm from the participants' face at eye level. During the first 45 seconds, the person was asked to think of three answers to the question "What might this be?" and to try and "Be creative in your responses." After 45 seconds, they were asked to verbalize their responses. The exact instructions were as follows: "I am now going to show you a series of ambiguous visual stimuli. I would like you to come up with three answers for each image to the question 'What might this be?' For the first minute or so, I want you to think of your three responses in your mind. After about one minute, I will ask you to tell me your responses. Try to be as still as you can while you are thinking of your three responses to the question 'What might this be?' Do you have any questions?"

The experimenter wrote down the three responses and the responses were also tape recorded. EEG was measured during the first 45 seconds when the participants were constructing their Rorschach response. EEG was not measured while participants were speaking. After each blot was completed, an assistant entered the experimental room and uncovered the next card to view.

After all six blots were completed, each participant completed about five minutes of follow up questions to determine the exact location of their Rorschach responses. Each participant was provided an achromatic reproduction of the blots (as shown in Appendix O) and asked to mark "where on the card they saw each of their responses." The participant was guided through this process by the experimenter in that their responses were read back to them and any questions they had about how to mark the location of their responses were addressed. After the participants completed the location sheet, the electrodes were removed and they were provided their course credit for that session and scheduled for session two.

Session Two

During the first hour of session two, participants completed a randomized set of personality measures, including the Tridimensional Personality Questionnaire, Eysenck Personality Questionnaire, Pleasure, Arousal, Dominance (PAD) Temperament scales, Globality-Differentiation Scale, and the Behavioral Inhibition Scale/Behavioral Activation Scale. Collectively, these questionnaires took approximately one hour to complete.

Initial preparation for EEG recording was completed exactly as in session one. Following baseline EEG recordings (two minutes of eyes closed), each participant was randomly assigned to either the positive or negative mood induction group. After the participant completed the baseline EEG recordings, the experimenter entered the room in which the participant was seated and handed them a packet of pages that contained the response sheets to be used in the remainder of the session. The participant was told to turn the pages only when the experimenter told them to and to place one page under the entire packet when they are through with each page. They rested the response packet on a “lap desk.”

First, the participant completed the pre-film mood state measures using a short form of the Positive and Negative Affect Scale (see Appendix J) and a short form of the Pleasure, Arousal, Dominance Emotion scale. The short form Positive and Negative Affect Scale was always administered first, followed by the short form Pleasure, Arousal, Dominance Emotion scale. Collectively, these measures took about two minutes to complete.

Immediately following pre-film mood measurement, each participant completed two verbal fluency tasks and two pre-film figural fluency tasks. The order of the verbal and figural fluency tasks was randomly assigned. Therefore, each participant completed either the two verbal fluency tasks followed by the two figural fluency tasks or vice versa. The instructions for the verbal fluency task were as follows: "I am going to say a letter of the alphabet and I want you to write down as many words as you can that begin with the letter that I say. The only rule is that you cannot use people names or place names. So, if the letter is B, you would not want to write Bob or Bangor. All other words besides people and place names are fine. I will tell you the letter, tell you to start and then tell you when to stop writing. Do you have any questions?"

The figural fluency task required a sample item to ensure that the participant understood the task. The experimenter entered the room in which the participant was sitting and turned the page in their response packet to the example for the figural fluency task. The instructions for the figural fluency were as follows: "Please look at the sheet in front of you. As you can see, there are boxes with dots inside each box. I want you to connect three or more dots together using straight lines and I want you to make a different pattern in each box." An example with three boxes was administered first to ensure that the participant understood the task. Following the example, the experimenter returned to the adjacent room and administered the full figural fluency task from by speaking through an intercom.

Collectively, the pre-film verbal and figural fluency tasks took approximately 6 minutes. After the fluency tasks were completed, lights were turned off in the experimental room where the participant sat and the film was shown (either happy or sad). The instructions for the film clip were as follows: "Now I am going to show you a brief film clip designed to influence your mood. I would like you to pay attention to the clip and try to engage yourself in the mood the film is trying to elicit."

Immediately following the film, participants completed a repeated measures verbal fluency and figural fluency task. If the participant completed the verbal fluency task before the figural fluency task before the mood induction, they completed the verbal task before the figural fluency task first following the mood induction. After the post-film mood measures were completed, another two minutes of eyes-closed resting EEG was recorded during which the participant relaxed with their eyes closed. Following this post-mood induction EEG recording, the electrodes were removed and the participant was debriefed and provided their credit for the session.

# CHAPTER 3: RESULTS

## Overview

The first step in analyzing the results was to examine potential gender differences on all of the measures included in this study. A summary of the EEG data will be presented next, focusing on descriptive statistics and EEG temporal stability. Following this, the results of each component of the experiment will be presented.

Correlation analyses were used to examine the temporal stability of EEG asymmetry and to examine some of the major hypotheses in each section of the study. Split-plot analysis of variance was used to examine group differences in EEG power density values and to examine the effect of the mood induction procedure on emotion, verbal and figural fluency, and EEG asymmetry. Two-tailed tests were always used.

## Gender Differences

Because males and females are known to differ consistently on some measures of personality and mood (e.g., neuroticism, negative affect; Eysenck & Eysenck, 1993), potential gender differences on the variables used in this study were examined. The only significant gender differences that emerged on any of the self-report measures were on the Eysenck Personality Questionnaire neuroticism scale, $t\ (66) = -2.08, p < .01$ and the Pleasure-Arousal-Dominance (PAD) Temperament Arousal scale, $t\ (66) = -3.26, p < .01$. On average, females scored higher on these scales. Therefore, all analyses except those involving the neuroticism and PAD Temperament Arousal scale were conducted using the entire sample. With the exception of the RAT, there were no significant gender differences on any of the creativity, fluency, or pre- and post-mood induction emotion measures. Males scored higher on the RAT than females, $t\ (66) = 2.36, p < .05$.

Appendix R summarizes the descriptive statistics for the creativity, mood, and personality measures used in this study. Gender differences were also examined on all EEG asymmetry measures and the results showed no significant differences between males and females.

EEG Asymmetry Data: Descriptive Statistics and Temporal Stability

Table 1 summarizes the descriptive statistics for the baseline EEG asymmetry data during session one. Table 2 summarizes the descriptive statistics for the EEG asymmetry data during the creative task. Table 3 summarizes the descriptive statistics for the EEG asymmetry values prior to the mood induction during session two. Table 4 summarizes the descriptive statistics for the EEG asymmetry values after the mood induction procedure during session two. Table 5 summarizes the averaged EEG asymmetry values across session one and session two baselines. Tables 6 through 10 summarize the temporal stability of EEG for each frequency band. Temporal stability was calculated using EEG from the session one baseline recordings and the session two baseline (pre-mood induction) recordings.

The temporal stability calculations indicated that EEG asymmetry in frontal, central, and parietal locations show a modest level of temporal stability when tested between two and three weeks apart. These results are slightly lower than previous research (Papousek & Schulter, 1998; Tomarken et al., 1992).

In addition to confirming a moderate level of temporal stability of EEG asymmetry across different scalp locations and frequency bands, this study replicated previous research showing that anterior asymmetry is essentially unrelated to posterior EEG asymmetry (Papousek & Schulter, 1998). This was true across all frequency bands.

Table 1

Descriptive Statistics for Baseline EEG Asymmetry During Session One.

| | Mean | SD |
|---|---|---|
| Delta Frontal Asymmetry | .03 | .15 |
| Delta Central Asymmetry | .01 | .16 |
| Delta Parietal Asymmetry | -.01 | .14 |
| Theta Frontal Asymmetry | .03 | .10 |
| Theta Central Asymmetry | .02 | .20 |
| Theta Parietal Asymmetry | -.16 | .19 |
| Alpha Frontal Asymmetry | .02 | .09 |
| Alpha Central Asymmetry | -.00 | .20 |
| Alpha Parietal Asymmetry | .02 | .27 |
| Beta 1 Frontal Asymmetry | -.00 | .15 |
| Beta 1 Central Asymmetry | -.03 | .28 |
| Beta 1 Parietal Asymmetry | .08 | .27 |
| Beta 2 Frontal Asymmetry | .04 | .19 |
| Beta 2 Central Asymmetry | .04 | .34 |
| Beta 2 Parietal Asymmetry | .15 | .18 |

Note. Positive values indicate greater relative left hemisphere activation. N = 68.

Table 2.

Descriptive Statistics for EEG Asymmetry During the Creative Task.

| | Mean | SD |
|---|---|---|
| Delta Frontal Asymmetry | .01 | .11 |
| Delta Central Asymmetry | -.00 | .16 |
| Delta Parietal Asymmetry | -.01 | .14 |
| Theta Frontal Asymmetry | .01 | .12 |
| Theta Central Asymmetry | -.01 | .23 |
| Theta Parietal Asymmetry | -.10 | .15 |
| Alpha Frontal Asymmetry | .03 | .13 |
| Alpha Central Asymmetry | .04 | .26 |
| Alpha Parietal Asymmetry | .02 | .21 |
| Beta 1 Frontal Asymmetry | .04 | .23 |
| Beta 1 Central Asymmetry | -.02 | .29 |
| Beta 1 Parietal Asymmetry | .05 | .47 |
| Beta 2 Frontal Asymmetry | .04 | .41 |
| Beta 2 Central Asymmetry | -.02 | .40 |
| Beta 2 Parietal Asymmetry | .16 | .19 |

Note. Positive values indicate greater relative left hemisphere activation. N = 68.

Table 3.

Descriptive Statistics for Pre-Mood Induction EEG Asymmetry During Session Two.

| | Mean | SD |
|---|---|---|
| Delta Frontal Asymmetry | .00 | .18 |
| Delta Central Asymmetry | -.01 | .17 |
| Delta Parietal Asymmetry | -.02 | .11 |
| Theta Frontal Asymmetry | .01 | .12 |
| Theta Central Asymmetry | .04 | .20 |
| Theta Parietal Asymmetry | -.18 | .20 |
| Alpha Frontal Asymmetry | .00 | .11 |
| Alpha Central Asymmetry | -.01 | .18 |
| Alpha Parietal Asymmetry | .02 | .26 |
| Beta 1 Frontal Asymmetry | -.02 | .18 |
| Beta 1 Central Asymmetry | -.04 | .24 |
| Beta 1 Parietal Asymmetry | .04 | .23 |
| Beta 2 Frontal Asymmetry | .02 | .22 |
| Beta 2 Central Asymmetry | .01 | .35 |
| Beta 2 Parietal Asymmetry | .10 | .15 |

Note. Positive values indicate greater relative left hemisphere activation. N = 57.

Table 4

Descriptive Statistics for Post-Mood Induction EEG Asymmetry During Session Two.

| | Mean | SD |
|---|---|---|
| Delta Frontal Asymmetry | .05 | .16 |
| Delta Central Asymmetry | .03 | .20 |
| Delta Parietal Asymmetry | -.01 | .12 |
| Theta Frontal Asymmetry | .01 | .11 |
| Theta Central Asymmetry | .01 | .26 |
| Theta Parietal Asymmetry | -.22 | .22 |
| Alpha Frontal Asymmetry | -.01 | .11 |
| Alpha Central Asymmetry | -.07 | .25 |
| Alpha Parietal Asymmetry | .01 | .26 |
| Beta 1 Frontal Asymmetry | -.03 | .17 |
| Beta 1 Central Asymmetry | .03 | .23 |
| Beta 1 Parietal Asymmetry | .04 | .28 |
| Beta 2 Frontal Asymmetry | -.01 | .17 |
| Beta 2 Central Asymmetry | -.01 | .27 |
| Beta 2 Parietal Asymmetry | .13 | .21 |

Note. Positive values indicate greater relative left hemisphere activation. N = 57.

Table 5

Descriptive Statistics for EEG Asymmetry Averaged Across Session One and Session Two Baselines.

| | Mean | SD |
|---|---|---|
| Delta Frontal Asymmetry | .01 | .14 |
| Delta Central Asymmetry | .01 | .14 |
| Delta Parietal Asymmetry | -.01 | .10 |
| Theta Frontal Asymmetry | .02 | .09 |
| Theta Central Asymmetry | .03 | .16 |
| Theta Parietal Asymmetry | -.18 | .16 |
| Alpha Frontal Asymmetry | .01 | .09 |
| Alpha Central Asymmetry | -.01 | .17 |
| Alpha Parietal Asymmetry | .02 | .23 |
| Beta 1 Frontal Asymmetry | -.01 | .14 |
| Beta 1 Central Asymmetry | -.03 | .23 |
| Beta 1 Parietal Asymmetry | .05 | .19 |
| Beta 2 Frontal Asymmetry | .03 | .18 |
| Beta 2 Central Asymmetry | .02 | .30 |
| Beta 2 Parietal Asymmetry | .12 | .11 |

Note. Positive values indicate greater relative left hemisphere activation. N = 57.

Table 6

Correlations between Session One Baseline and Session Two Baseline Pre-Mood Induction EEG Asymmetry for the Delta Frequency Band.

| | S1 F | S1 C | S1 P | S2 F | S2 C | S2 P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .15 | | | | | |
| S1 Parietal Asymmetry | -.07 | .20 | | | | |
| S2 Frontal Asymmetry | .47*** | .04 | -.17 | | | |
| S2 Central Asymmetry | .03 | .43*** | .22 | .09 | | |
| S2 Parietal Asymmetry | .00 | -.08 | .22 | .07 | .16 | |

Note. S1 = Session one; S2 = Session two; S1 F = Session one Frontal Asymmetry; S1 C = Session one Central Asymmetry; S1 P = Session one Parietal Asymmetry; S2 F = Session two Frontal Asymmetry; S2 C = Session two Central Asymmetry; S2 P = Session two Parietal Asymmetry. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 7

Correlations between Session One Baseline and Session Two Baseline Pre-Mood Induction EEG Asymmetry for the Theta Frequency Band.

| | S1 F | S1 C | S1 P | S2 F | S2 C | S2 P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .20 | | | | | |
| S1 Parietal Asymmetry | -.05 | .38** | | | | |
| S2 Frontal Asymmetry | .49*** | -.17 | -.19 | | | |
| S2 Central Asymmetry | .00 | .40** | .02 | .13 | | |
| S2 Parietal Asymmetry | -.08 | .04 | .42** | .11 | .04 | |

Note. S1 = Session one; S2 = Session two; S1 F = Session one Frontal Asymmetry; S1 C = Session one Central Asymmetry; S1 P = Session one Parietal Asymmetry; S2 F = Session two Frontal Asymmetry; S2 C = Session two Central Asymmetry; S2 P = Session two Parietal Asymmetry. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 8

Correlations between Session One Baseline and Session Two Baseline Pre-Mood Induction EEG Asymmetry for the Alpha Frequency Band.

| | S1 F | S1 C | S1 P | S2 F | S2 C | S2 P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .21 | | | | | |
| S1 Parietal Asymmetry | .02 | .36** | | | | |
| S2 Frontal Asymmetry | .49*** | .00 | .05 | | | |
| S2 Central Asymmetry | .09 | .55*** | -.08 | .30** | | |
| S2 Parietal Asymmetry | -.10 | .03 | .56*** | -.15 | -.19 | |

Note. S1 = Session one; S2 = Session two; S1 F = Session one Frontal Asymmetry; S1 C = Session one Central Asymmetry; S1 P = Session one Parietal Asymmetry; S2 F = Session two Frontal Asymmetry; S2 C = Session two Central Asymmetry; S2 P = Session two Parietal Asymmetry. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 9

Correlations between Session One Baseline and Session Two Baseline Pre-Mood Induction EEG Asymmetry for the Beta 1 Frequency Band.

| | S1 F | S1 C | S1 P | S2 F | S2 C | S2 P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .35** | | | | | |
| S1 Parietal Asymmetry | -.03 | .33** | | | | |
| S2 Frontal Asymmetry | .51*** | .25 | .05 | | | |
| S2 Central Asymmetry | .18 | .61*** | .32** | .28* | | |
| S2 Parietal Asymmetry | .15 | .06 | .21 | .10 | .19 | |

Note. S1 = Session one; S2 = Session two; S1 F = Session one Frontal Asymmetry; S1 C = Session one Central Asymmetry; S1 P = Session one Parietal Asymmetry; S2 F = Session two Frontal Asymmetry; S2 C = Session two Central Asymmetry; S2 P = Session two Parietal Asymmetry. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 10

Correlations between Session One Baseline and Session Two Baseline Pre-Mood Induction EEG Asymmetry for the Beta 2 Frequency Band.

| | S1 F | S1 C | S1 P | S2 F | S2 C | S2 P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .31** | | | | | |
| S1 Parietal Asymmetry | .11 | .28* | | | | |
| S2 Frontal Asymmetry | .47*** | .14 | .07 | | | |
| S2 Central Asymmetry | .12 | .48*** | .20 | .13 | | |
| S2 Parietal Asymmetry | -.08 | -.05 | .19 | -.08 | .11 | |

Note. S1 = Session one; S2 = Session two; S1 F = Session one Frontal Asymmetry; S1 C = Session one Central Asymmetry; S1 P = Session one Parietal Asymmetry; S2 F = Session two Frontal Asymmetry; S2 C = Session two Central Asymmetry; S2 P = Session two Parietal Asymmetry. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Although a major focus of this research is on EEG asymmetry, the question of the temporal stability of power density in individual sites is important to examine. The results indicate that the temporal stability at individual sites is higher than EEG asymmetry. Table 11 summarizes the results of these analyses.

As with the EEG asymmetry temporal stability, these values are consistent with previous research and demonstrate that power density at individual leads is, at least for the Alpha and Theta bands, quite stable across a two to three week time period. Delta power stability at individual electrode sites is expected to be lower than other bands (see Papousek & Schulter, 1998).

Previous research has documented the potential importance of distinguishing between those participants that show relative stability of their EEG asymmetry versus those that do not (Davidson et al., 1995; Tomarken et al., 1992). In order to examine a subset of subjects that showed high levels of EEG asymmetry stability across both sessions, the procedures used in previous research were followed (Tomarken et al., 1992). First, asymmetry values from both baseline sessions were standardized. If a subject's session one standardized EEG asymmetry value was within .3 standard deviations of their session two standardized EEG asymmetry value, they were considered to be in the stable group. In addition, a "relaxed" criterion of .5 standard deviations was used because it resulted in a slightly higher number of subjects in the stable group. Tables 12 through 16 summarize these analyses.

Using either stability criterion results in substantially larger temporal stability coefficients suggesting that some participants display more stable EEG asymmetry than others, which is consistent with previous research (Tomarken et al., 1992). In addition, it

Table 11

Temporal Stability of Power Density Values for Individual Electrode Sites and Different Frequency Bands.

| | Delta | Theta | Alpha | Beta 1 | Beta 2 |
|---|---|---|---|---|---|
| F3 | .50*** | .82*** | .79*** | .65*** | .71*** |
| F4 | .50*** | .82*** | .79*** | .65*** | .65*** |
| C3 | .44** | .78*** | .77*** | .61*** | .59*** |
| C4 | .39** | .80*** | .78*** | .62*** | .50*** |
| P3 | .58*** | .82*** | .76*** | .69*** | .67*** |
| P4 | .61*** | .81*** | .75*** | .64*** | .65*** |

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. N = 57.

Table 12

EEG Stability Analyses for Two Stability Criteria for the Delta Frequency Band.

| | .3 SD Criteria | | | | .5 SD Criteria | | | |
|---|---|---|---|---|---|---|---|---|
| | Stable | N | Unstable | N | Stable | N | Unstable | N |
| Frontal | .98*** | 18 | .28 | 39 | .96*** | 26 | .20 | 31 |
| Central | .95*** | 11 | .38* | 46 | .87*** | 20 | .36* | 37 |
| Parietal | .98*** | 15 | .00 | 42 | .97*** | 22 | -.17 | 35 |

Note. Correlations indicate the relationship between Session one and Session two baseline standardized EEG asymmetry values. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 13

EEG Stability Analyses for Two Stability Criteria for the Theta Frequency Band.

| | .3 SD Criteria | | | | .5 SD Criteria | | | |
|---|---|---|---|---|---|---|---|---|
| | Stable | N | Unstable | N | Stable | N | Unstable | N |
| Frontal | .98*** | 19 | .36* | 38 | .97*** | 26 | .11 | 31 |
| Central | .98*** | 26 | -.12 | 31 | .97*** | 34 | -.18 | 23 |
| Parietal | .98*** | 18 | .25 | 39 | .91*** | 28 | .21 | 29 |

Note. Correlations indicate the relationship between Session one and Session two baseline standardized EEG asymmetry values. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 14

EEG Stability Analyses for Two Stability Criteria for the Alpha Frequency Band.

| | .3 SD Criteria | | | | .5 SD Criteria | | | |
|---|---|---|---|---|---|---|---|---|
| | Stable | N | Unstable | N | Stable | N | Unstable | N |
| Frontal | .98*** | 17 | .30 | 40 | .95*** | 30 | .11 | 27 |
| Central | .97*** | 16 | .50** | 41 | .92*** | 26 | .45* | 31 |
| Parietal | .98*** | 22 | .37* | 35 | .96*** | 31 | .32 | 26 |

Note. Correlations indicate the relationship between Session one and Session two baseline standardized EEG asymmetry values. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 15

EEG Stability Analyses for Two Stability Criteria for the Beta 1 Frequency Band.

| | .3 SD Criteria | | | | .5 SD Criteria | | | |
|---|---|---|---|---|---|---|---|---|
| | Stable | N | Unstable | N | Stable | N | Unstable | N |
| Frontal | .67** | 29 | .42* | 28 | .40* | 40 | .07 | 17 |
| Central | .72*** | 17 | .38* | 40 | .77*** | 27 | .39* | 30 |
| Parietal | .40* | 20 | .13 | 37 | .37* | 38 | -.02 | 19 |

Note. Correlations indicate the relationship between Session one and Session two baseline standardized EEG asymmetry values. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 16

EEG Stability Analyses for Two Stability Criteria for the Beta 2 Frequency Band.

| | .3 SD Criteria | | | | .5 SD Criteria | | | |
|---|---|---|---|---|---|---|---|---|
| | Stable | N | Unstable | N | Stable | N | Unstable | N |
| Frontal | .99*** | 20 | .23 | 37 | .97*** | 26 | .18 | 31 |
| Central | .91*** | 17 | .46** | 40 | .88*** | 27 | .42* | 30 |
| Parietal | .95*** | 15 | .02 | 42 | .82*** | 28 | -.02 | 29 |

Note. Correlations indicate the relationship between Session one and Session two baseline standardized EEG asymmetry values. N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

appears that the correlations are only mildly attenuated when using the "relaxed" .5 standard deviation criterion compared to the more stringent .3 standard deviation criterion and that the gain in number of subjects in the stable group increases by approximately one third to one half across all groups.

Consistent Findings Across All EEG Analyses

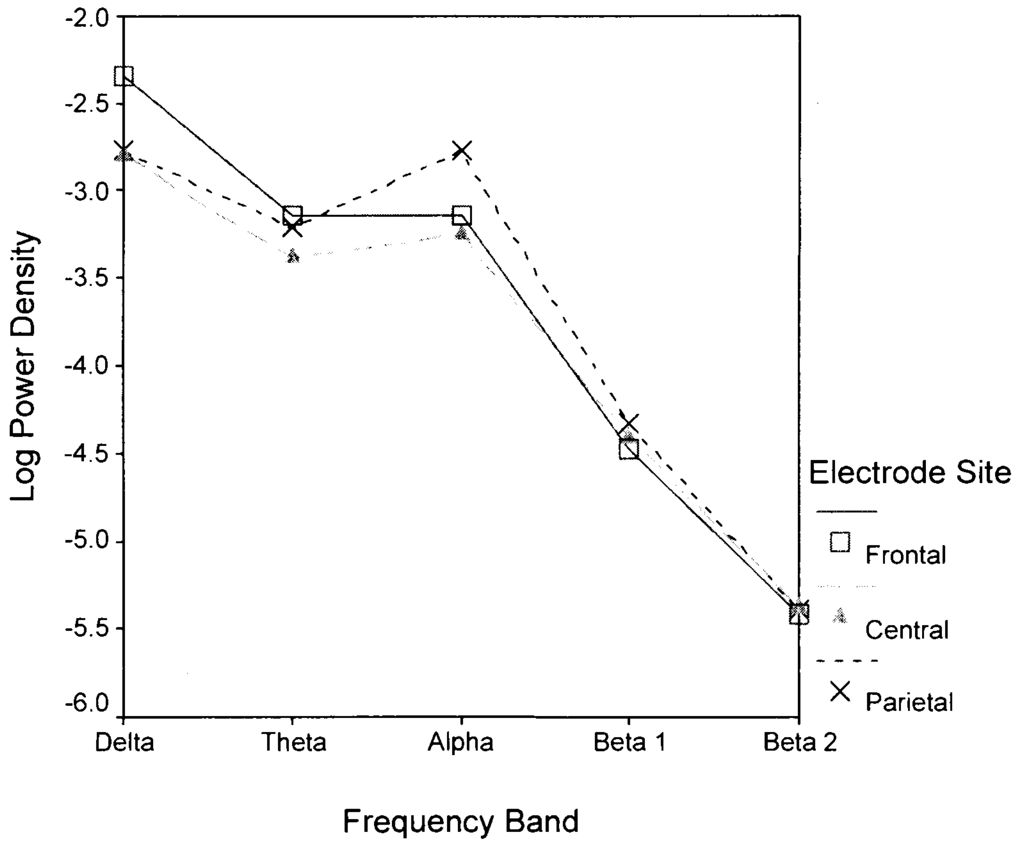
In order to facilitate understanding of the analyses that follow, it will be helpful to consider some of the consistent relationships found between natural log power density values of the five frequency bands examined in the present study. Figure 1 depicts the log power density values across each of the five frequency bands for each electrode site (frontal, central, parietal) for the resting baseline EEG recordings during session one.

As Figure 1 shows, there are large differences in the natural log power density values across the five frequency bands. This is expected and consistent with the other research (Kwiatkowski, 2002). It is important to remember that because natural log power density was used, instead of raw spectral power, the values are negative.

The interpretation of the natural log power density values require that the reader keep in mind that the more negative the power density value, the smaller the overall raw power values. For example, the natural log of .05 is equal to -2.99537. The natural log of .08 is -2.5273. *Thus, the smaller value for raw spectral power (i.e., .05) results in a more negative number when transformed using the natural log.* Because the raw power density values for the Beta 1 and Beta 2 log power density values are the smallest, they are the most negative log power density values. In other words, because raw spectral power in these frequency bands is much lower than those of the Delta, Theta, and Alpha bands, the log power density values are the most negative for these two bands. The effect

Figure 1

Log Power Density Values for Each Frequency Band and Electrode Site During Session One Resting Baseline.



of this with respect to the MANOVA results reported in the present study, which include each frequency band as a within-subjects variable, is that there will always be a significant difference in log power density between the frequency bands. This simply reflects the fact that the log power density values are different from one another.

In addition to consistent within-group differences across frequency bands, there are also consistent Band by Site interactions. These effects reflect the fact that within certain frequency bands, power at different sites consistently differed from one another. For example, within the Delta frequency band, frontal log density power is consistently higher than the other two sites. Interestingly, this is exactly what Kwiatkowski (2002) recently reported for the Delta band. See Figure 2 for an illustration of this finding.

Another example of a consistent effect across all EEG analyses was for the Alpha band. It is well known that Alpha waves are more easily detected and more prevalent in posterior cortex when compared to anterior cortex. This finding is illustrated in Figure 3, which shows that the log power density values for the parietal sites are less negative (which translates into higher values if one were examining the un-transformed values) than the other two electrode sites.

For the present study, a consistent Band by Hemisphere by Site effect was found in the MANOVA analyses. For the session one resting baseline EEG data, this effect is found strongly for the Theta band. Figure 4 illustrates the fact that on average, right hemisphere parietal log power density was less than left hemisphere parietal log power density.

This finding makes sense in light of the findings from the Theta parietal asymmetry values for session one shown in Table 1 above. Notice that the value for the

Figure 2

Delta Log Power Density by Hemisphere and Electrode Site for Session One Resting Baseline.

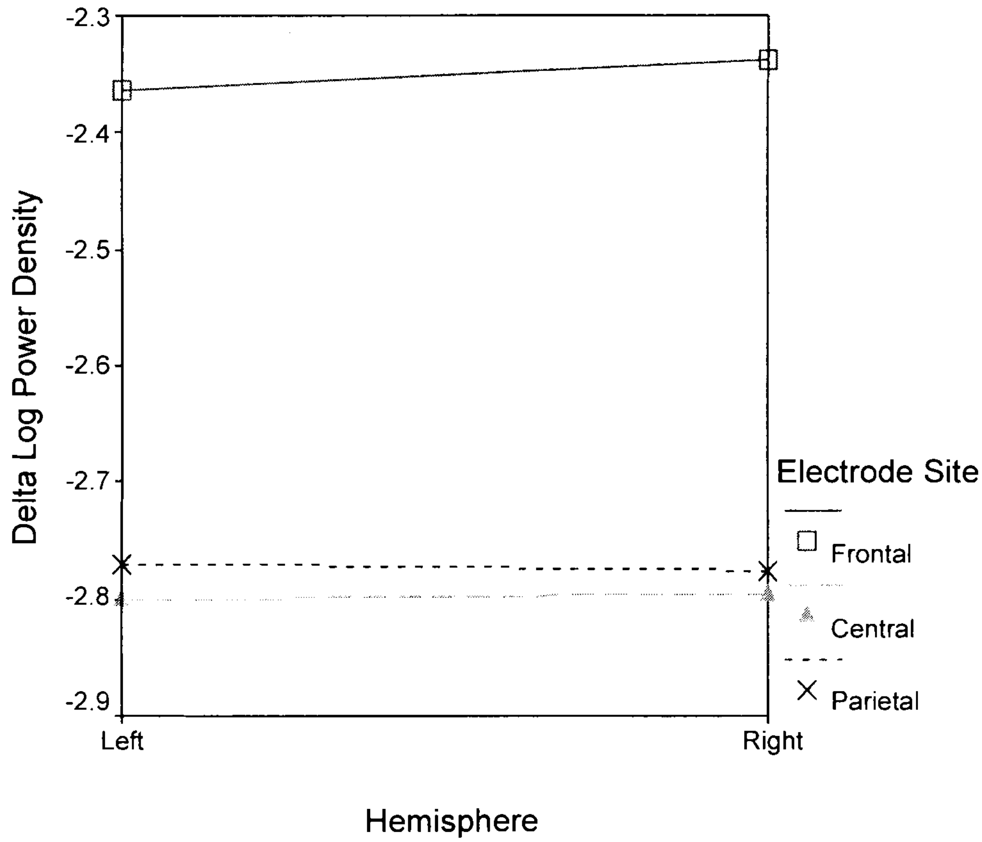


Figure 3

Alpha Log Power Density by Hemisphere by Site for Session One Resting Baseline.

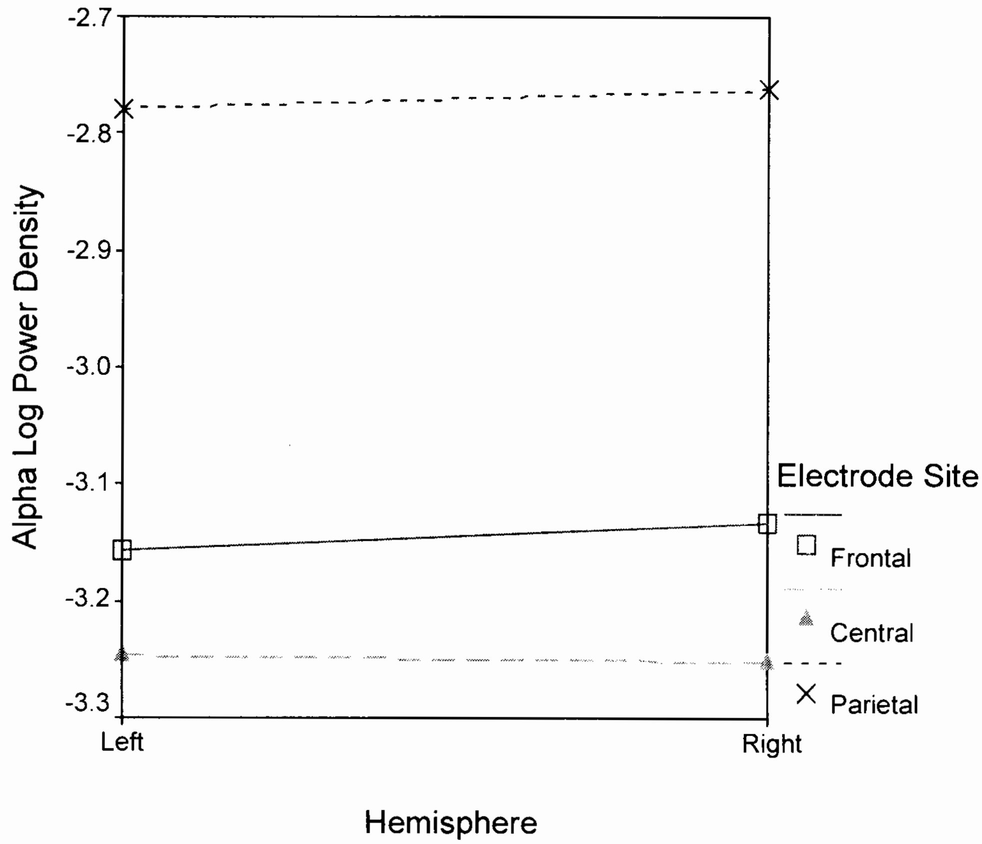
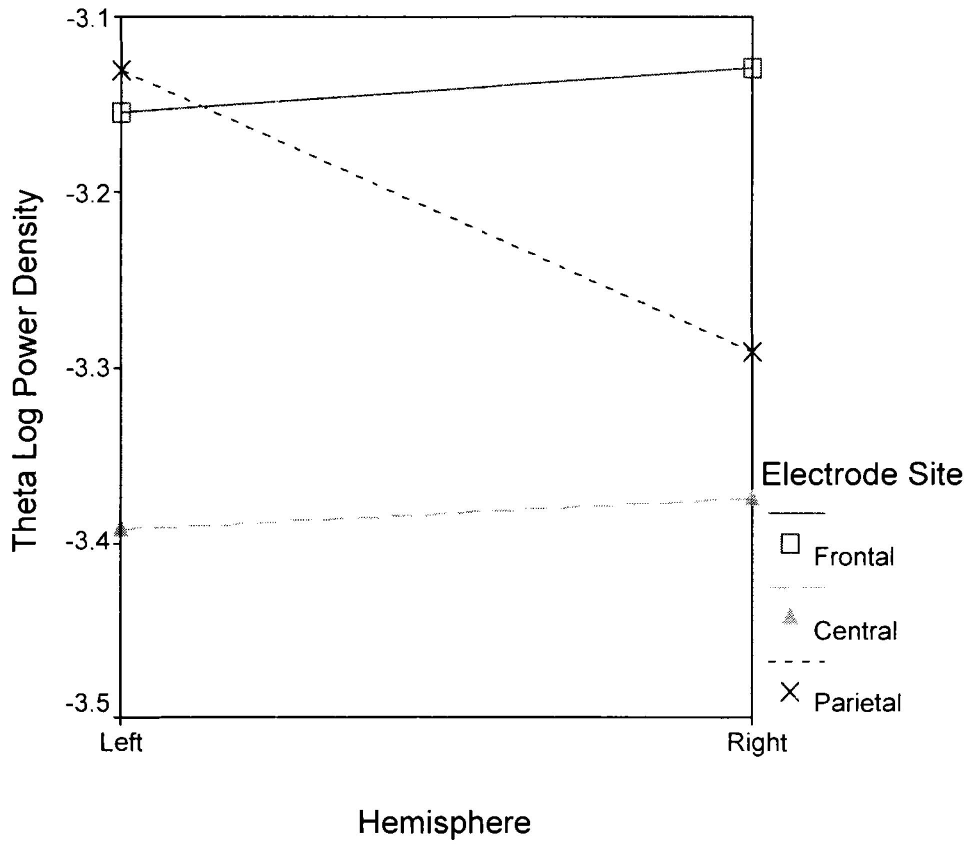


Figure 4

Theta Log Power Density by Hemisphere and Site for Session One Resting Baseline.



parietal asymmetry score in the Theta band is negative. In fact, it is the most negative asymmetry value found in the asymmetry values for session one (i.e., -.16). Indeed, across all EEG measurement sessions, Theta parietal asymmetry tended to be the most negative asymmetry value across all sites and frequency bands.

Finally, it is important to keep in mind that *lower* relative natural log power density within a frequency band is interpreted as *greater* activation. This is the standard interpretation of Alpha power and some argue that this rule of thumb is also applicable to the other bands (Davidson et al., 1995). However, even though there is evidence to apply this interpretation to Theta in addition to Alpha, the extent to which this interpretation applies to Delta, Beta 1, and Beta 2 bands is questionable (Buchtel, personal communication, 2003).

## Hierarchical Visual Processing, Emotion, Personality and Posterior EEG Asymmetry

In this section, the results for the hierarchical visual analysis component of the present study are summarized. The interrelations among the measures of hierarchical visual analysis will be described first, followed by the results concerning hierarchical visual analysis and mood, personality and posterior EEG asymmetry.

### Interrelationships among Measures of Hierarchical Visual Analysis

It was predicted that Rorschach location scores would correlate significantly with performance on the Global-Local task such that Whole and Minor Detail Rorschach location responses would correlate negatively with performance on the Global-Local task and Major Detail Rorschach responses would correlate positively with performance on the Global-Local task. (Higher scores on the Global-Local task indicate greater global responding and vice versa). As described in the Method section, blots I and IV were more likely to elicit Whole responses, blots III and X were more likely to elicit a Major Detail response, and blots II and VIII were about equally likely to elicit a Whole or a Major Detail response, indicating that averaging location responses across blots could obscure potential relationships between Global-Local task performance and location responses on the Rorschach. Therefore, in order to test the possibility that the relationship between Global-Local task performance and Rorschach location scores are different for different subsets of inkblots, average location scores were calculated for blots I and IV, II and VIII, and III and X and were correlated with performance on the Global-Local task. Table 17 outlines the descriptive statistics for the global-local task and the Rorschach location scores for all six blots. Tables 18 through 21 summarize the results of these analyses. Following the approach used by Basso et al. (1996), the Global-Local scores were arcsin transformed to normalize the distribution, which was negatively skewed because global responses were more common than local responses on average.

The results of these analyses indicated that considering all six of the blots together, no relationship exists between Global-Local task performance and Rorschach location responses. Considering the subsets of inkblots based on their tendency to elicit certain Rorschach location responses, the only significant correlation that emerged was a negative relationship between Whole responses on cards II and VIII and global responses on the Global-Local task.

Table 17

Descriptive Statistics for Measures of Hierarchical Visual Processing.

| | Mean | SD |
|---|---|---|
| Global-Local Task[a] | .88 | .37 |
| Whole Rorschach Responses | 6.88 | 3.20 |
| Major Detail Rorschach Responses | 7.38 | 3.24 |
| Minor Detail Rorschach Responses | 2.50 | 1.62 |

Note. [a] arcsin transformed scores. N = 68.

Table 18

Correlation Matrix for Measures of Hierarchical Visual Analysis.

| | GL Task | W | D |
|---|---|---|---|
| GL Task | | | |
| W | .00 | | |
| D | .03 | -.67*** | |
| Dd | -.06 | -.32** | -.22 |

Note. GL Task = Global Local Task; W = Whole Rorschach responses to all six inkblots; D = Major Detail Rorschach response to all six inkblots; Dd = Minor Detail Rorschach response to all six inkblots. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 19

Correlation Matrix for Global-Local Task and Rorschach Cards I and IV.

| | GL Task | W I-IV | D I-IV |
|---|---|---|---|
| GL Task | | | |
| W I-IV | .09 | | |
| D I-IV | -.02 | -.53*** | |
| Dd I-IV | -.06 | -.54*** | -.28* |

Note. GL Task = Global Local Task; W I-IV = Whole Rorschach responses to cards I and IV; D = Major Detail Rorschach responsesto cards I and IV; Dd = Minor Detail Rorschach responses to cards I and IV. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 20

Correlation Matrix for Global-Local Task and Rorschach Cards II and VIII.

| | GL Task | W II - VIII | D II - VIII |
|---|---|---|---|
| GL Task | | | |
| W II - VIII | -.25* | | |
| D II - VIII | .21 | -.73*** | |
| Dd II - VIII | -.03 | -.30* | -.23 |

Note. GL Task = Global Local Task; W II - VIII = Whole Rorschach responses to cards II and VIII; D II - VIII = Major Detail Rorschach responsesto cards II and VIII; Dd II - VIII = Minor Detail Rorschach responses to cards II and VIII. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 21

Correlation Matrix for Global-Local Task and Rorschach Cards III and X.

| | GL Task | W III - X | D III - X |
|---|---|---|---|
| GL Task | | | |
| W III - X | .19 | | |
| D III - X | -.10 | -.63*** | |
| Dd III - X | -.01 | -.14 | -.27* |

Note. GL Task = Global Local Task; W III - X = Whole Rorschach responses to cards III and X; D III - X = Major Detail Rorschach responses to cards III and X; Dd III - X = Minor Detail Rorschach responses to cards III and X. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Overall, these results failed to support the hypothesized relations between Global-Local task performance on Rorschach location responses. In addition, the Rorschach location responses for subsets of the inkblots did not correlate with the Global-Local task in the hypothesized directions. Although the one significant negative correlation between Whole responses and global responses suggested potential support for the idea that Whole responses are related to local visual processing, this finding occurred on a subset of blots that are equally likely to elicit a Whole or a Major Detail Rorschach location response. Therefore, this finding is of questionable significance and does not support the original hypothesis.

Hierarchical Visual Processing and Mood

The next set of analyses examined the relationship between hierarchical visual processing and mood. It was predicted that negative mood would correlate with hierarchical visual analysis on the Global-Local task and the Rorschach such that greater negative mood would predict local processing. Conversely, it was predicted that measures of positive emotion would correlate significantly with global processing tendencies. Due to the possibility that the relationship between mood and hierarchical visual processing on the Rorschach could depend on the subset of blots used, the correlations between mood and location responses were conducted for all six blots combined as well as the subsets of the blots. Tables 22 through 25 summarize the results of these analyses.

The results of these analyses found little support for a relation between performance on the Global-Local task and mood. Thus, this study failed to replicate the findings of Basso et al. (1996) who did find a positive relationship between performance on the same Global-Local task and mood such that greater negative mood (as measured by the BDI-II and STAI-T) was associated with more local responses.

The results of the analyses examining the relationship between Rorschach location scores found support for the hypothesis that Minor Detail responses on the Rorschach are associated with higher scores on measures of negative emotion and lower scores on some measures of positive emotion. The relationship between negative emotion and Minor Detail responses was significant for all six blots combined using the negative affect scale of the Positive and Negative Affect Scale. In addition, Minor Detail

Rorschach responses were significantly negatively associated with pleasure scores using the Pleasure subscale of the Pleasure, Arousal, Dominance (PAD) Emotion scale. Across

Table 22

Correlations between Mood Variables and Measures of Hierarchical Visual Processing.

| | BDI-II | STAI-T | PA | NA | PAD-P | PAD-A |
|---|---|---|---|---|---|---|
| Global-Local | .06 | .10 | .20 | .24 | .00 | .05 |
| W | .03 | -.15 | .09 | .04 | .15 | -.05 |
| D | .05 | .07 | .17 | -.09 | -.06 | .28* |
| Dd | .17 | .18 | -.21 | .33** | -.28* | -.04 |

Note. Global-Local = Global-Local task performance; W = Whole Rorschach responses to all six cards; D = Major Detail Rorschach responses to all six cards; Dd = Minor Detail Rorschach responses to all six cards; BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait Anxiety; PA = Positive Affect scale of the Positive and Negative Affect Scale; NA = Negative Affect scale of the Positive and Negative Affect Scale; PAD-P = Pleasure subscale of the PAD Emotion Scale; PAD-A = Arousal subscale of the PAD Emotion scales. N = 68.

* $p < .05$, ** $p < .01$.

Table 23

Correlations between Mood Variables and Rorschach Location Responses (Cards I and IV).

| | BDI-II | STAI-T | PA | NA | PAD-P | PAD-A |
|---|---|---|---|---|---|---|
| W I-IV | -.06 | -.19 | .15 | -.08 | .14 | -.08 |
| D I-IV | .10 | .12 | .10 | -.05 | -.11 | .25* |
| Dd I-IV | .10 | .11 | -.15 | .24* | -.03 | .00 |

Note. W I-IV = Whole Rorschach responses to inkblots I and IV; D = Major Detail Rorschach responses to inkblots I and IV; Dd = Minor Detail Rorschach responses to inkblots I and IV; BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait Anxiety; PA = Positive Affect scale of the Positive and Negative Affect Scale; NA = Negative Affect scale of the Positive and Negative Affect Scale; PAD-P = Pleasure scale of the PAD Emotion Scales; PAD-A = Arousal scale of the PAD Emotion scales. N = 68.

* $p < .05$, ** $p < .01$.

Table 24

Correlations between Mood Variables and Rorschach Location Responses (Cards II and VIII).

| | BDI-II | STAI-T | PA | NA | PAD-P | PAD-A |
|---|---|---|---|---|---|---|
| W II-VIII | .07 | -.09 | -.07 | -.02 | .06 | -.14 |
| D II-VIII | -.13 | -.08 | .27 | -.16 | .04 | .21 |
| Dd II-VIII | .23 | .26* | -.19 | .37** | -.24 | .04 |

Note. W II - VIII = Whole Rorschach responses to cards II and VIII; D II - VIII = Major Detail Rorschach responses to cards II and VIII; Dd II - VIII = Minor Detail Rorschach responses to cards II and VIII; BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait Anxiety; Positive Affect = Positive Affect scale of the Positive and Negative Affect Scale; Negative Affect = Negative Affect scale of the Positive and Negative Affect Scale. N = 68.

* $p < .05$, ** $p < .01$.

Table 25

Correlations between Mood Variables and Rorschach Location Responses (Cards III and X).

| | BDI-II | STAI-T | PA | NA | PAD-P | PAD-A |
|---|---|---|---|---|---|---|
| W III-X | -.03 | -.10 | .09 | .14 | .16 | .11 |
| D III-X | .08 | .03 | .15 | -.05 | -.08 | .21 |
| Dd III-X | .25* | .20 | -.15 | .21 | -.27* | -.09 |

Note. W III-X = Whole Rorschach responses to cards III and X; D III-X = Major Detail Rorschach responses to cards III and X; Dd III-X = Minor Detail Rorschach responses to cards III and X; BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait Anxiety; Positive Affect = Positive Affect scale of the Positive and Negative Affect Scale; Negative Affect = Negative Affect scale of the Positive and Negative Affect Scale. N = 68.

* $p < .05$.

all combinations of the subsets of inkblots, the pattern of correlations between Minor Detail location responses and mood were similar and at times significant. Therefore, these findings lend support to the notion that increases in Minor Detail responses on the Rorschach are associated with increased negative emotional experience and decreased positive emotional experience.

Hierarchical Visual Processing and Personality

The next set of hypotheses examined the relationship between hierarchical visual processing and personality. It was predicted that performance on the Global-Local task would correlate negatively with neuroticism and positively with extraversion, behavioral activation, optimism and Mehrabian's (1996) Globality-Differentiation scale (GDS). Similarly, Whole and Minor Detail responses on the Rorschach were predicted to correlate positively with neuroticism and negatively with extraversion, behavioral activation, optimism and the GDS.

Table 26 outlines the results of the correlations between the global-local task and select personality variables. As indicated, a number of personality traits were positively correlated with global-local task performance, including extraversion, the BAS scale, and the Globality-Differentiation scale. Higher scores on the Global-Local task indicate relatively more global responses. Optimism and neuroticism did not correlate significantly with the global-local task.

These findings support the view that performance on the Global-Local task is related to personality, but not exactly in the way proposed by Basso et al. (1996). The findings in the present study suggest that traits associated with extraversion, behavioral activation, and the merging of thoughts and feeling as indexed by higher scores on the

Table 26

Correlation Matrix for Global-Local Task and Personality Measures.

| | GL Task | E | N | LOT | GDS |
|---|---|---|---|---|---|
| GL Task | | | | | |
| E | .24* | | | | |
| N | .03 | -.24* | | | |
| LOT | .00 | .23 | -.39*** | | |
| GDS | .35** | .06 | .55*** | -.37** | |
| BAS | .28* | .46*** | -.09 | .18 | .26* |

Note. GL Task = Global-Local Task; E = Extraversion; N = Neuroticism; LOT = Life Orientation Test (Optimism - Pessimism); GDS = Globality-Differentiation Scale; BAS = Behavioral Activation Scale-Average. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Globality-Differentiation Scale are positively correlated with performance on the Global-Local task.

Although extraversion and behavioral activation are correlated with one another, the Globality-Differentiation Scale was uncorrelated with extraversion, but was significantly correlated with behavioral activation. This suggested that a combination of these personality traits might best predict global visual processing tendencies. Indeed, post-hoc, stepwise regression analyses using the Globality-Differentiation Scale and the Extraversion scale revealed that the combination of these two measures accounted for 15 percent of the variance in hierarchical visual processing scores ($F = 6.71, p = .002$).

With two exceptions, Rorschach location scores were not systematically correlated with personality measures. Scores on the Harm Avoidance and Neuroticism scales were positively correlated at the $p = .05$ level with Minor Detail responses, but only for the subset of inkblots containing the average location scores on blots III and X. This finding is not unexpected given that these two personality measures are significantly correlated with measures of negative emotion.

Hierarchical Visual Process and Parietal EEG Asymmetry

The final set of hypotheses in this component of the present study dealt with the relationship between posterior EEG asymmetry and measures of hierarchical visual analysis. It was predicted that hierarchical visual analysis would relate to asymmetric cerebral activation such that relatively greater right parietal activation would be associated with increased global processing tendencies and relatively greater left parietal activation would be associated with local processing tendencies. In order to test these hypotheses, a split-plot analysis of variance was conducted using Global-Local task performance (high versus low groups) as the independent variable. The within subject variables were the power density values of session one in parietal regions of both hemispheres (P3, P4) and all five frequency bands. This analysis is shown in Table 27. The results failed to support the hypothesized interaction between hemisphere and Global-Local visual analysis performance for any of the frequency bands.

A similar set of analyses were conducted using Rorschach location scores as the between groups variable instead of scores on the Global-Local task. Scores for the Whole location responses across all six blots were categorized into high and low groups using a median split. Table 28 summarizes the result of a split-plot analysis of variance

Table 27

Band by Parietal Hemisphere (P3-P4) by Global-Local Group (High versus Low) for the Power Density Values During Session One Baseline.

| Source | df | MS | F |
|---|---|---|---|
| Band | 4 | 177.49 | 411.45*** |
| Band x GL-HL | 4 | .45 | 1.04 |
| Error | 264 | .43 | |
| Hemi | 1 | .04 | .68 |
| Hemi x GL-HL | 1 | .01 | .12 |
| Error | 66 | .06 | |
| Band x Hemi | 4 | .45 | 22.47*** |
| Band x Hemi x GL-HL | 4 | .01 | .55 |
| Error | 264 | .02 | |

Note. Band = Frequency band (Delta, Theta, Alpha, Beta1, Beta2); Hemi = Hemisphere; GL - HL = Global-local task performance high versus low groups based on a median split. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

using Whole Rorschach location response groups (high versus low) as the independent variable and frequency band and parietal hemisphere activation as the within subject variables. The results failed to support the hypothesized interaction between hemisphere and Rorschach location scores for any of the frequency bands.

Based on the fact that some participants showed stable EEG asymmetry across two to three weeks and others did not, the possibility existed that a relationship between global-local visual processing would be evident only for those participants who showed stable parietal EEG asymmetries. In order to investigate this possibility, a series of split-plot analysis of variance tests were conducted to examine the possible interaction of Global-Local group and EEG stability group. It was necessary to run separate analyses for each band because the subjects in the stable and unstable EEG groups differed across each frequency band. These analyses failed to reveal any meaningful relationship between Global-Local group and EEG stability group. A similar set of analyses were conducted using Rorschach location scores as the independent variable (high versus low Whole groups) and the results also showed no statistically significant results.

In summary, the results of these analyses failed to reveal any meaningful relationship between EEG power density in parietal regions and indices of global-local visual processing using either the Global-Local task or Rorschach location responses. In addition, the comparison of stable versus unstable parietal EEG asymmetry groups did not show a relationship between hierarchical visual analysis and parietal cortical activation. Although only the results using the .5 standard deviation criterion to delineate stable and unstable groups was presented here, the results were no different using the .3 standard deviation criterion for EEG asymmetry stability.

Table 28

Band by Parietal Hemisphere (P3-P4) by Whole Rorschach Location Group (High versus Low) for Power Density in Parietal Regions During Session One Baseline.

| Source | df | MS | F |
|---|---|---|---|
| Band | 4 | 177.31 | 405.16*** |
| Band x Whole | 4 | .04 | .08 |
| Error | 264 | .44 | |
| Hemi | 1 | .04 | .71 |
| Hemi x Whole | 1 | .00 | .01 |
| Error | 66 | .06 | |
| Band x Hemi | 4 | .46 | 22.83*** |
| Band x Hemi x Whole | 4 | .01 | .59 |
| Error | 264 | .02 | |

Note. Band = Frequency band (Delta, Theta, Alpha, Beta1, Beta2); Hemi = Hemisphere (left, right); Whole = Whole Rorschach location response groups (high versus low groups based on a median split). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

## Creativity, Primary Process Cognition, Personality and EEG Asymmetry

### Interrelationships among Creativity Measures

The first set of hypotheses to be tested in this component of the study was the interrelationships among the various measures of creativity. Tables 29 through 31 summarize the results of these analyses.

Regarding the relationship between the Regressive Imagery Dictionary (RID) variables and the creativity measures, the results indicated that the Primary Process percentage score was positively correlated with the composite creativity measure. Of note, the correlation between the RAT and the Primary Process variables were in the predicted direction but fell just short of being statistically significant. The RID variables were significantly correlated with the CDS Immersion subscale and the pattern of correlations for the overall CDS score was in the predicted direction but failed to reach statistical significance.

Regarding the relationship between the Cognitive Disinhibition Scale (CDS) and the self-report (CPS) and performance based measures of creativity (AUT, RAT), the pattern of correlations supported the construct validity of the CDS as a *correlate* of creative potential. The overall CDS score and the CDS Flexibility scale were significantly correlated with the AUT, CPS and the composite creative potential score.

### Creativity and EEG Asymmetry

It was predicted that during the creative task, high creative participants would show greater activation of the right hemisphere compared to low creative participants. In addition, the possibility that resting baseline EEG asymmetry would relate to creative potential such that greater creative potential would be evident in those with greater

Table 29

Correlations between RID Variables and Creativity Measures.

| | AUT | RAT | CPS | Composite Creative |
|---|---|---|---|---|
| PP | .06 | .21 | .20 | .24* |
| PP-SP | .02 | .21 | .17 | .20 |
| SP | .05 | -.14 | -.07 | -.08 |

Note. PP = Primary Process; PP - SP = Primary Process minus Secondary Process; SP = Secondary Process; Creativity Composite = Composite Creativity Measure (Average of standardized AUT, RAT, and CPS); AUT = Alternate Uses Test; RAT = Remote Associates Test; CPS = Creative Personality Scale. N = 68.

* $p < .05$.

Table 30

Correlations between Cognitive Disinhibition Scale and Creativity Measures.

| | AUT | RAT | CPS | Composite Creative |
|---|---|---|---|---|
| AUT | | | | |
| RAT | .15 | | | |
| CPS | .27* | .09 | | |
| CDS | .26* | .12 | .39** | .38** |
| CDS - I | .21 | .16 | .32** | .35** |
| CDS - F | .25* | .06 | .36** | .34** |

Note. Composite Creative = Composite Creativity Measure (Average of standardized AUT, RAT, and CPS); AUT = Alternate Uses Test; RAT = Remote Associates Test; CPS = Creative Personality Scale; CDS = Cognitive Disinhibition Scale; CDS-I = Immersion subscale of the CDS; CDS-F = Flexibility subscale of the CDS. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 31

Correlations between Regressive Imagery Dictionary Variables and CDS.

| | PP | SP | PP-SP |
|---|---|---|---|
| PP | | | |
| SP | -.46*** | | |
| CDS | .19 | -.18 | .22 |
| CDS-I | .27* | -.14 | .25* |
| CDS - F | .09 | -.19 | .16 |

Note. PP = Primary Process; SP = Secondary Process, PP - SP = Primary Process minus Secondary Process, Creativity = Composite Creativity Measure; CDS = Cognitive Disinhibition Scale; CDS-I = Immersion subscale of the CDS; CDS-F = Flexibility subscale of the CDS. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

relative activation of the right hemisphere was examined. The creative task used in this study was defined as the time the participants were constructing their Rorschach responses. EEG power density during the resting baseline of session one was used as the comparison task (as opposed to the averaged resting baseline EEG power density from both sessions) because an equal number of subjects (N=68) completed the resting baseline of session one and the creative task. Table 32 summarizes the results of a split-plot multivariate analysis of variance using the composite creative potential measure (high versus low creative potential) as the between subject variable and task (resting baseline during session one versus creative task), hemisphere (left, right), frequency band (Delta, Theta, Alpha, Beta1, Beta2), and site (Frontal, Central, Parietal) as the within subject variables.

Considering the critical interactions between task, hemisphere, and creativity group, no statistically significant results emerged from this analysis. The significant main effects that did emerge were for Task, Band, and Site. The differences between Bands have been described earlier and simply reiterate the fact that the power density values differed across different frequency bands. The significant effect of Task indicated that the overall power density values differed significantly between the two tasks.

Before moving on, the significant effect for Task in Table 32 must be noted. This effect indicated that the log power density values when combined across all frequency bands were significantly different across the two tasks. This effect is most likely due to the combination of two issues. First, it appears that the nature of the task influenced the absolute level of power density values. Compared to when the participants were resting in a relaxed state with their eyes closed, they were alert and actively thinking with their

Table 32

Task (Resting versus Creative Task) by Band by Site by Hemisphere by Creative Potential (High versus Low).

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 117.79 | 66.98*** |
| Task x C - HL | 1 | 1.28 | .73 |
| Error | 66 | 1.75 | |
| Band | 4 | 862.55 | 641.98*** |
| Band x C - HL | 4 | .26 | .20 |
| Error | 264 | 1.34 | |
| Site | 2 | 11.73 | 29.46*** |
| Site x C - HL | 2 | .33 | .82 |
| Error | 132 | .40 | |
| Hemi | 1 | .20 | 1.33 |
| Hemi x C - HL | 1 | .31 | 2.03 |
| Error | 66 | .15 | |
| Task x Band | 4 | 44.37 | 116.62*** |
| Task x Band x C - HL | 4 | .76 | 2.00 |
| Error | 264 | .38 | |
| Task x Site | 2 | 5.62 | 34.13*** |
| Task x Site x C - HL | 2 | .01 | .04 |
| Error | 132 | .17 | |
| Band x Site | 10 | 4.28 | 33.27*** |

Table 32 Continued

| | | | |
|---|---|---|---|
| Band x Site x C - HL | 10 | .20 | 1.55 |
| Error | 528 | .13 | |
| Task x Band x Site | 10 | .91 | 12.19*** |
| Task x Band x C - HL | 10 | .07 | .89 |
| Error | 528 | .07 | |
| Task x Hemi | 1 | .00 | .00 |
| Task x Hemi x C - HL | 1 | .01 | .38 |
| Error | 66 | .03 | |
| Band x Hemi | 4 | .31 | 9.71*** |
| Band x Hemi x C - HL | 4 | .02 | .64 |
| Error | 264 | .03 | |
| Task x Band x Hemi | 4 | .01 | 1.01 |
| Task x Band x Hemi x C - HL | 4 | .00 | .03 |
| Error | 264 | .01 | |
| Site x Hemi | 2 | .04 | .58 |
| Site x Hemi x C - HL | 2 | .10 | 1.30 |
| Error | 132 | .07 | |
| Task x Site x Hemi | 2 | .00 | .23 |
| Task x Site x Hemi x C - HL | 2 | .00 | .20 |
| Error | 132 | .02 | |
| Band x Site x Hemi | 10 | .25 | 9.87*** |
| Band x Site x Hemi x C - HL | 10 | .01 | .51 |

Table 32 Continued

| | | | |
|---|---|---|---|
| Error | 528 | .03 | |
| Task x Band x Site x Hemi | 10 | .02 | 2.40* |
| Task x Hemi x Site x Hemi x C - HL | 10 | .00 | .410 |
| Error | 528 | .01 | |

Note. Task = Creative task versus resting baseline; Band = Frequency band (Delta, Theta, Alpha, Beta1, Beta2); Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); C - HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

eyes open during the creative task (i.e., constructing Rorschach responses). Although the overall power appears to reduce across these conditions, it is important to note that the asymmetry values across all frequency bands between the creative task and the resting baseline of session one remain significantly correlated with one another. The correlation matrix between the creative task asymmetry values and the session one baseline asymmetry values are provided in Appendix T. Important to recognize, however, is that one would not want these values to be too highly correlated. If this were the case, the effect of the creative task on asymmetry would not be detectable.

The second reason for the difference in power density values across tasks is due to the fact that the creative task power density values were computed by averaging six separate samples, one from each trial of the six inkblot responses. A result of this averaging process was a lowering of the variance for the creative task power density values in comparison to the values for the obtained during the session one resting baseline recordings. In addition, there were more epochs available for the creative task power density variables in comparison to the session one resting baseline samples. As discussed in the Method section, there was an average of 51.22 epochs for the creative task recordings and an average of 36.53 epochs for the session one resting baseline data. It appears as though these task differences and underlying statistical differences in combination likely account for the differences in power density values for the creative task in comparison with the resting baseline EEG data. Figure 5 depicts the log power density values for each band during each task.

Figure 5 shows a marked difference in power density for the Alpha band, with greater power density values during the resting state for the Alpha band compared to during the creative task. The most likely reason for this finding reflects the well-known fact that Alpha frequencies are enhanced when a person is in a relaxed state with their eyes closed (Davidson, 1995). Tables 33 through 37 summarize the results regarding power density across tasks within each frequency band using the composite creative potential measure (high versus low) as the between subjects variable.

Considering only the Theta frequency band, once again the main effects of Task and Site, and the Task by Site interaction were significant. Figure 6 depicts the Theta log power density values for each site across tasks. The figure shows that overall power was greater during the resting baseline and that this was especially true for the parietal electrode locations.

The next set of analyses used high and low groups on the Cognitive Disinhibition Scale (CDS) to examine potential task and hemisphere differences across the two tasks. Tables 38 through 43 summarize the results of these analyses.

The results of this analysis indicate that there was a significant interaction between Hemisphere and CDS group. Figure 7 depicts the power density values for each hemisphere and each CDS group.

As shown in Figure 7, the high creative group had relatively greater activation of the right hemisphere compared to the left and the low creative group showed the opposite pattern. There was also a nearly significant Task by Band by Hemisphere by CDS group interaction. Because this finding included all frequency bands together, it was important to examine each band individually. Therefore, follow-up MANOVAs were conducted and summarized in Tables 39 through 43.

Figure 5

Log Power Density for Each Frequency Band During the Creative Task and Resting Baseline.

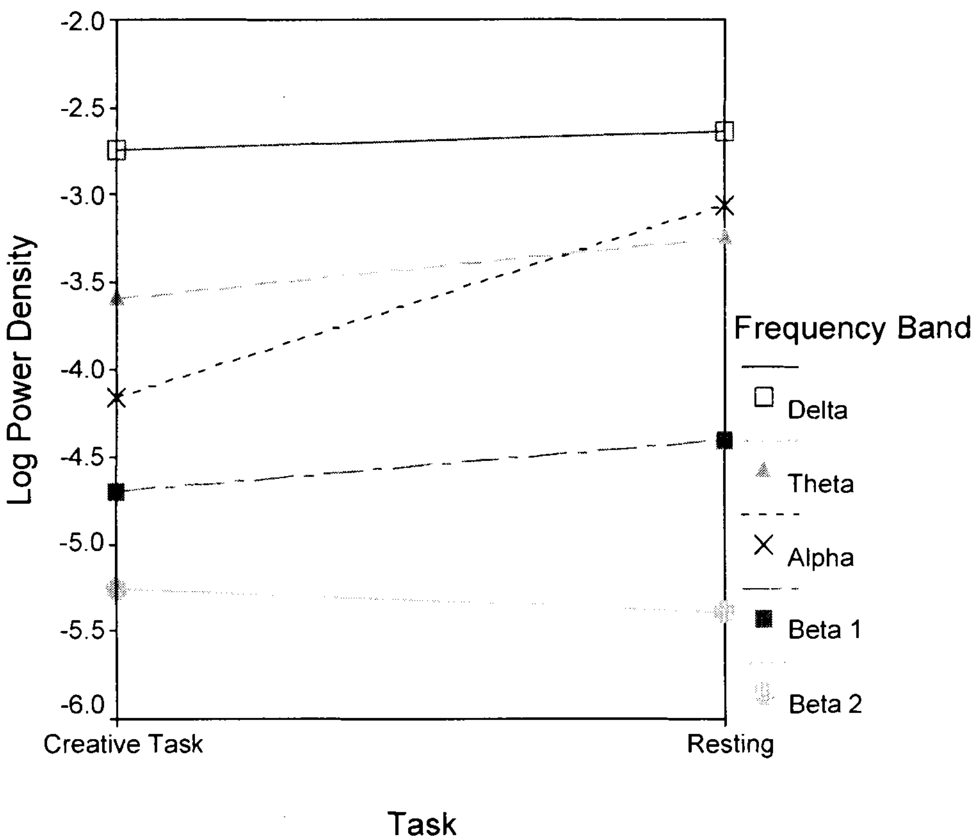


Table 33

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Delta Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 2.07 | 7.54** |
| Task x C - HL | 1 | .07 | .26 |
| Error | 66 | .28 | |
| Site | 2 | 14.60 | 139.13*** |
| Site x C - HL | 2 | .04 | .34 |
| Error | 132 | .11 | |
| Hemi | 1 | .00 | .09 |
| Hemi x C - HL | 1 | .01 | .55 |
| Error | 66 | .02 | |
| Task x Site | 2 | .12 | 4.63* |
| Task x Site x C - HL | 2 | .04 | 1.43 |
| Error | 132 | .03 | |
| Task x Hemi | 1 | .01 | .83 |
| Task x Hemi x C - HL | 1 | .00 | .29 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .01 | .86 |
| Site x Hemi x C - HL | 2 | .01 | .93 |
| Error | 132 | .01 | |
| Task x Site x Hemi | 2 | .00 | .12 |

Table 33 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x C - HL | 2 | .00 | .05 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); C - HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 34

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Theta Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 24.49 | 51.31*** |
| Task x C - HL | 1 | .13 | .27 |
| Error | 66 | .48 | |
| Site | 2 | 5.92 | 29.39*** |
| Site x C - HL | 2 | .34 | 1.68 |
| Error | 132 | .20 | |
| Hemi | 1 | .32 | 8.33** |
| Hemi x C - HL | 1 | .03 | .75 |
| Error | 66 | .04 | |
| Task x Site | 2 | .90 | 39.44*** |
| Task x Site x C - HL | 2 | .08 | 3.28* |
| Error | 132 | .02 | |
| Task x Hemi | 1 | .00 | .01 |
| Task x Hemi x C - HL | 1 | .02 | 1.44 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .49 | 26.50*** |
| Site x Hemi x C - HL | 2 | .03 | 1.50 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .03 | 7.65*** |

Table 34 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x C - HL | 2 | .00 | .54 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); C - HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 6

Theta Log Power Density for Task and Electrode Site.

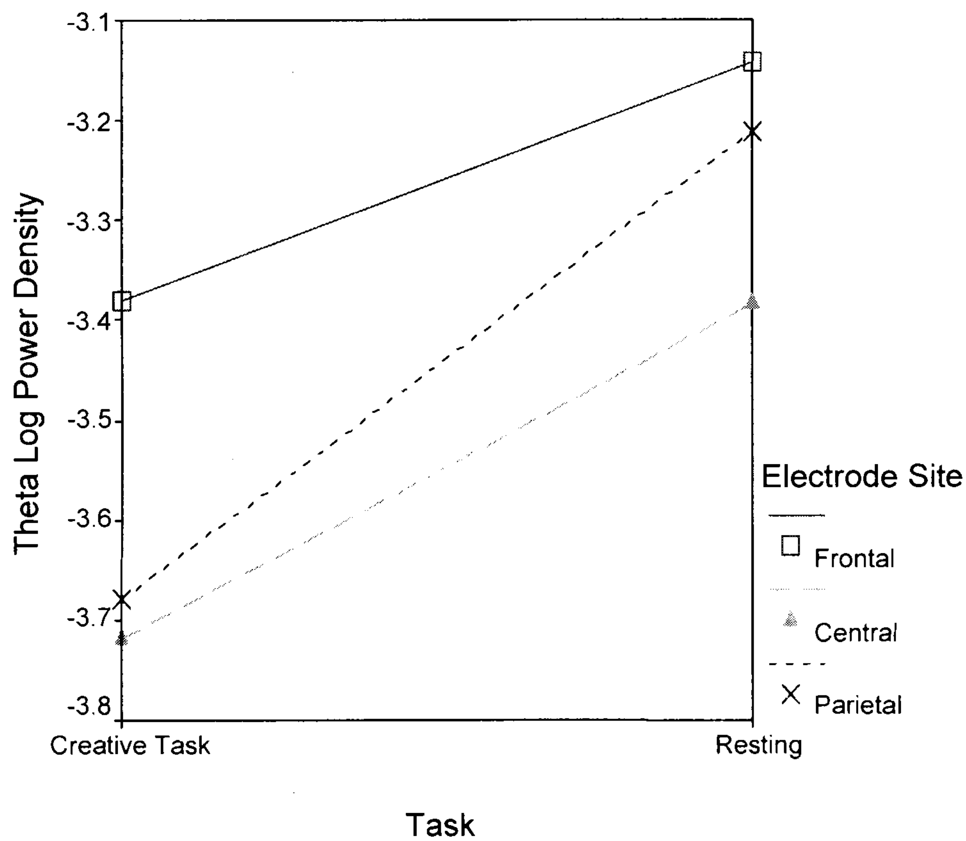


Table 35

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Alpha Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 247.21 | 180.95*** |
| Task x C - HL | 1 | .06 | .05 |
| Error | 66 | 1.36 | |
| Site | 2 | 5.58 | 28.06*** |
| Site x C - HL | 2 | .09 | .47 |
| Error | 132 | .20 | |
| Hemi | 1 | .07 | 1.40 |
| Hemi x C - HL | 1 | .03 | .57 |
| Error | 66 | .05 | |
| Task x Site | 2 | 3.80 | 53.05*** |
| Task x Site x C - HL | 2 | .04 | .58 |
| Error | 132 | .07 | |
| Task x Hemi | 1 | .01 | .51 |
| Task x Hemi x C - HL | 1 | .00 | .29 |
| Error | 66 | .02 | |
| Site x Hemi | 2 | .00 | .01 |
| Site x Hemi x C - HL | 2 | .00 | .07 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .01 | 1.55 |

Table 35 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x C - HL | 2 | .00 | .16 |
| Error | 132 | .01 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); C - HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 36

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Beta1 Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 17.42 | 33.94*** |
| Task x C - HL | 1 | .15 | .30 |
| Error | 66 | .51 | |
| Site | 2 | .14 | .70 |
| Site x C - HL | 2 | .28 | 1.39 |
| Error | 132 | .20 | |
| Hemi | 1 | .07 | .76 |
| Hemi x C - HL | 1 | .14 | 1.47 |
| Error | 66 | .09 | |
| Task x Site | 2 | 1.42 | 9.95*** |
| Task x Site x C - HL | 2 | .07 | .51 |
| Error | 132 | .14 | |
| Task x Hemi | 1 | .01 | .23 |
| Task x Hemi x C - HL | 1 | .01 | .21 |
| Error | 66 | .02 | |
| Site x Hemi | 2 | .13 | 2.26 |
| Site x Hemi x C - HL | 2 | .01 | .20 |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.23 |

Table 36 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x C - HL | 2 | .01 | .36 |
| Error | 132 | .02 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); C - HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 37

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Beta2 Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 4.07 | 6.26* |
| Task x C - HL | 1 | 3.90 | 6.01* |
| Error | 66 | .65 | |
| Site | 2 | 2.59 | 12.68** |
| Site x C - HL | 2 | .38 | 1.84 |
| Error | 132 | .20 | |
| Hemi | 1 | 1.00 | 12.51** |
| Hemi x C - HL | 1 | .19 | 2.38 |
| Error | 66 | .08 | |
| Task x Site | 2 | 3.00 | 15.10** |
| Task x Site x C - HL | 2 | .04 | .22 |
| Error | 132 | .20 | |
| Task x Hemi | 1 | .01 | .29 |
| Task x Hemi x C - HL | 1 | .00 | .09 |
| Error | 66 | .03 | |
| Site x Hemi | 2 | .42 | 6.74** |
| Site x Hemi x C - HL | 2 | .10 | 1.54 |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.11 |

Table 37 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x C - HL | 2 | .01 | .30 |
| Error | 132 | .02 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); C - HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 38

Task (Resting versus Creative Task) by Band by Site by Hemisphere by Cognitive Disinhibition Group (High versus Low).

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 118.86 | 68.85*** |
| Task x CDS-HL | 1 | 3.39 | 1.96 |
| Error | 66 | 1.73 | |
| Band | 4 | 864.25 | 674.97*** |
| Band x CDS-HL | 4 | 4.43 | 3.46** |
| Error | 264 | 1.28 | |
| Site | 2 | 11.68 | 29.04*** |
| Site x CDS-HL | 2 | .07 | .17 |
| Error | 132 | .40 | |
| Hemi | 1 | .18 | 1.24 |
| Hemi x CDS-HL | 1 | .81 | 5.60* |
| Error | 66 | .15 | |
| Task x Band | 4 | 44.29 | 114.15*** |
| Task x Band x CDS-HL | 4 | .26 | .68 |
| Error | 264 | .39 | |
| Task x Site | 2 | 5.61 | 34.29*** |
| Task x Site x CDS-HL | 2 | .07 | .41 |
| Error | 132 | .16 | |
| Band x Site | 8 | 4.25 | 33.20*** |

Table 38 Continued

| | | | |
|---|---|---|---|
| Band x Site x CDS-HL | 8 | .23 | 1.82 |
| Error | 528 | .13 | |
| Task x Band x Site | 8 | .91 | 12.29*** |
| Task x Band x CDS-HL | 8 | .09 | 1.17 |
| Error | 528 | .07 | |
| Task x Hemi | 1 | .00 | .01 |
| Task x Hemi x CDS-HL | 1 | .03 | .96 |
| Error | 66 | .03 | |
| Band x Hemi | 4 | .32 | 9.84*** |
| Band x Hemi x CDS-HL | 4 | .03 | .98 |
| Error | 264 | .03 | |
| Task x Band x Hemi | 4 | .01 | .49 |
| Task x Band x Hemi x CDS-HL | 4 | .03 | 2.24 |
| Error | 264 | .01 | |
| Site x Hemi | 2 | .05 | .64 |
| Site x Hemi x CDS-HL | 2 | .14 | 1.86 |
| Error | 132 | .07 | |
| Task x Site x Hemi | 2 | .00 | .21 |
| Task x Site x Hemi x CDS-HL | 2 | .02 | 1.11 |
| Error | 132 | .02 | |
| Band x Site x Hemi | 8 | .25 | 9.84*** |

Table 38 Continued

| | | | |
|---|---|---|---|
| Band x Site x Hemi x CDS-HL | 8 | .01 | .25 |
| Error | 528 | .02 | |
| Task x Band x Site x Hemi | 8 | .02 | 2.41* |
| Task x Band x Site x Hemi x CDS-HL | 8 | .01 | 1.36 |
| Error | 528 | .01 | |

Note. Task = Creative task versus resting baseline; Band = Frequency band (Delta, Theta, Alpha, Beta1, Beta2); Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); CDS-HL = Cognitive Disinhibition Scale (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 7

Overall Log Density Power Across Hemispheres for Cognitive Disinhibition Scale (High versus Low) Groups.

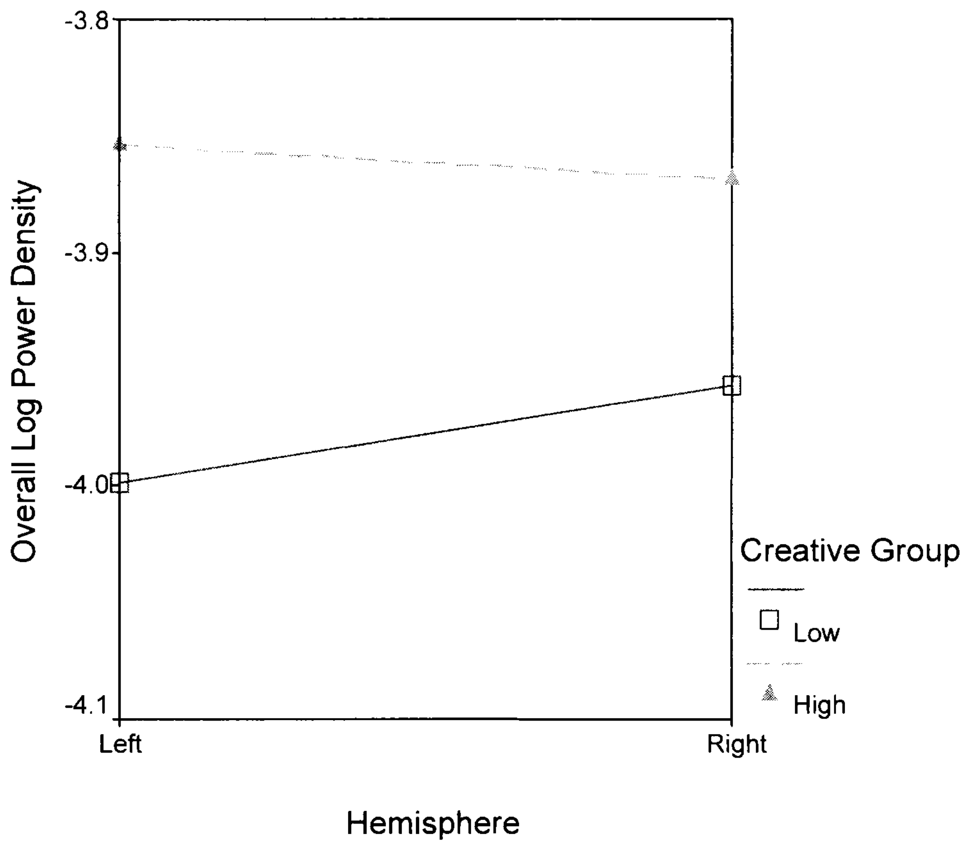


Table 39

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Delta Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 2.12 | 7.78** |
| Task x CDS-HL | 1 | .27 | .99 |
| Error | 66 | .27 | |
| Site | 2 | 14.53 | 139.77*** |
| Site x CDS-HL | 2 | .10 | .96 |
| Error | 132 | .10 | |
| Hemi | 1 | .00 | .06 |
| Hemi x CDS-HL | 1 | .07 | 3.48 |
| Error | 66 | .02 | |
| Task x Site | 2 | .13 | 4.72** |
| Task x Site x CDS-HL | 2 | .03 | .99 |
| Error | 132 | .03 | |
| Task x Hemi | 1 | .01 | .89 |
| Task x Hemi x CDS-HL | 1 | .01 | .80 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .01 | .90 |
| Site x Hemi x CDS-HL | 2 | .02 | 1.71 |
| Error | 132 | .01 | |
| Task x Site x Hemi | 2 | .00 | .11 |

Table 39 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x CDS-HL | 2 | .00 | .44 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); CDS-HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 40

Task by Site by Hemisphere by Cognitive Disinhibition Group (High versus Low) Split-Plot MANOVA on the Theta Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 24.72 | 52.82*** |
| Task x CDS-HL | 1 | .74 | 1.58 |
| Error | 66 | .47 | |
| Site | 2 | 5.86 | 28.99*** |
| Site x CDS-HL | 2 | .30 | 1.46 |
| Error | 132 | .20 | |
| Hemi | 1 | .33 | 9.59** |
| Hemi x CDS-HL | 1 | .24 | 7.01** |
| Error | 66 | .04 | |
| Task x Site | 2 | .90 | 37.61*** |
| Task x Site x CDS-HL | 2 | .01 | .43 |
| Error | 132 | .03 | |
| Task x Hemi | 1 | .00 | 0.03 |
| Task x Hemi x CDS-HL | 1 | .03 | 3.24 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .49 | 27.61*** |
| Site x Hemi x CDS-HL | 2 | .07 | 4.11* |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .03 | 7.72*** |

Table 40 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x CDS-HL | 2 | .00 | .75 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); CDS-HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 41

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Alpha Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 247.86 | 183.05*** |
| Task x CDS-HL | 1 | .86 | .64 |
| Error | 66 | 1.35 | |
| Site | 2 | 5.57 | 27.99*** |
| Site x CDS-HL | 2 | .10 | .53 |
| Error | 132 | .20 | |
| Hemi | 1 | .06 | 1.36 |
| Hemi x CDS-HL | 1 | .42 | 9.49** |
| Error | 66 | .04 | |
| Task x Site | 2 | 3.80 | 52.61*** |
| Task x Site x CDS-HL | 2 | .01 | .07 |
| Error | 132 | .07 | |
| Task x Hemi | 1 | .01 | .45 |
| Task x Hemi x CDS-HL | 1 | .09 | 6.45* |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .00 | .01 |
| Site x Hemi x CDS-HL | 2 | .04 | 1.56 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .01 | 1.60 |

Table 41 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x CDS-HL | 2 | .00 | .46 |
| Error | 132 | .01 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); CDS-HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 42

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Beta 1 Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 17.45 | 33.91*** |
| Task x CDS-HL | 1 | .05 | .10 |
| Error | 66 | .52 | |
| Site | 2 | .15 | .76 |
| Site x CDS-HL | 2 | .35 | 1.74 |
| Error | 132 | .20 | |
| Hemi | 1 | .06 | .69 |
| Hemi x CDS-HL | 1 | .17 | 1.82 |
| Error | 66 | .09 | |
| Task x Site | 2 | 1.44 | 10.08*** |
| Task x Site x CDS-HL | 2 | .08 | .55 |
| Error | 132 | .14 | |
| Task x Hemi | 1 | .01 | .24 |
| Task x Hemi x CDS-HL | 1 | .00 | .01 |
| Error | 66 | .02 | |
| Site x Hemi | 2 | .14 | 2.30 |
| Site x Hemi x CDS-HL | 2 | .01 | .12 |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.30 |

Table 42 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x CDS-HL | 2 | .01 | .43 |
| Error | 132 | .02 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); CDS-HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 43

Task by Site by Hemisphere by Creative Potential Group Split-Plot MANOVA on the Beta 2 Frequency Band Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 3.88 | 5.79* |
| Task x CDS-HL | 1 | 2.52 | 3.76 |
| Error | 66 | .67 | |
| Site | 2 | 2.57 | 12.37*** |
| Site x CDS-HL | 2 | .15 | .73 |
| Error | 132 | .21 | |
| Hemi | 1 | .98 | 12.01*** |
| Hemi x CDS-HL | 1 | .04 | .49 |
| Error | 66 | .08 | |
| Task x Site | 2 | 3.00 | 15.37*** |
| Task x Site x CDS-HL | 2 | .29 | 1.51 |
| Error | 132 | .20 | |
| Task x Hemi | 1 | .01 | .27 |
| Task x Hemi x CDS-HL | 1 | .02 | .65 |
| Error | 66 | .03 | |
| Site x Hemi | 2 | .42 | 6.65** |
| Site x Hemi x CDS-HL | 2 | .02 | .32 |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.05 |

Table 43 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x CDS-HL | 2 | .05 | 2.79 |
| Error | 132 | .02 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); CDS-HL = Creative potential group (high versus low) based on the composite creative potential measure. N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

The primary findings in this series of analyses, which contrasted high and low groups using the Cognitive Disinhibition Scale, showed that higher scores on the Cognitive Disinhibition Scale were associated with in an overall tendency for relatively greater right hemisphere activation in the Theta and Alpha bands regardless of task involvement. In addition, the significant Task by Hemisphere by CDS group for the Alpha band indicated that the relative differences in asymmetric activation between high creative and low creative participants (as defined using the CDS) were enhanced during the creative task.

Figures 8, 9, 10, and 11 help illuminate these results. Figure 8 depicts the Hemisphere by CDS group interaction for the Theta band, which shows clearly that the high CDS group manifested relatively greater right hemisphere Theta activation and the low creative group did not. This effect did not depend on task performance, although it is noteworthy that the Task by Hemisphere by CDS group approached statistical significance.

Figure 9 depicts the overall hemisphere by CDS group interaction regardless of task for the Alpha band, which shows that the high creative group demonstrated relatively greater right hemisphere Alpha activation and the low creative group demonstrated relatively greater left hemisphere Alpha activation.

Figures 10 and 11 help understand the interaction between task, hemisphere and CDS group for the Alpha band. Figure 10 shows the Alpha log power density values during the resting baseline measurement, which shows a similar pattern as found regardless of task. Figure 11 shows the Alpha log power density values during the creative task for each hemisphere and each CDS group.

Figure 8

Theta Log Power Density Across Both Hemispheres for the CDS Groups (High versus Low).

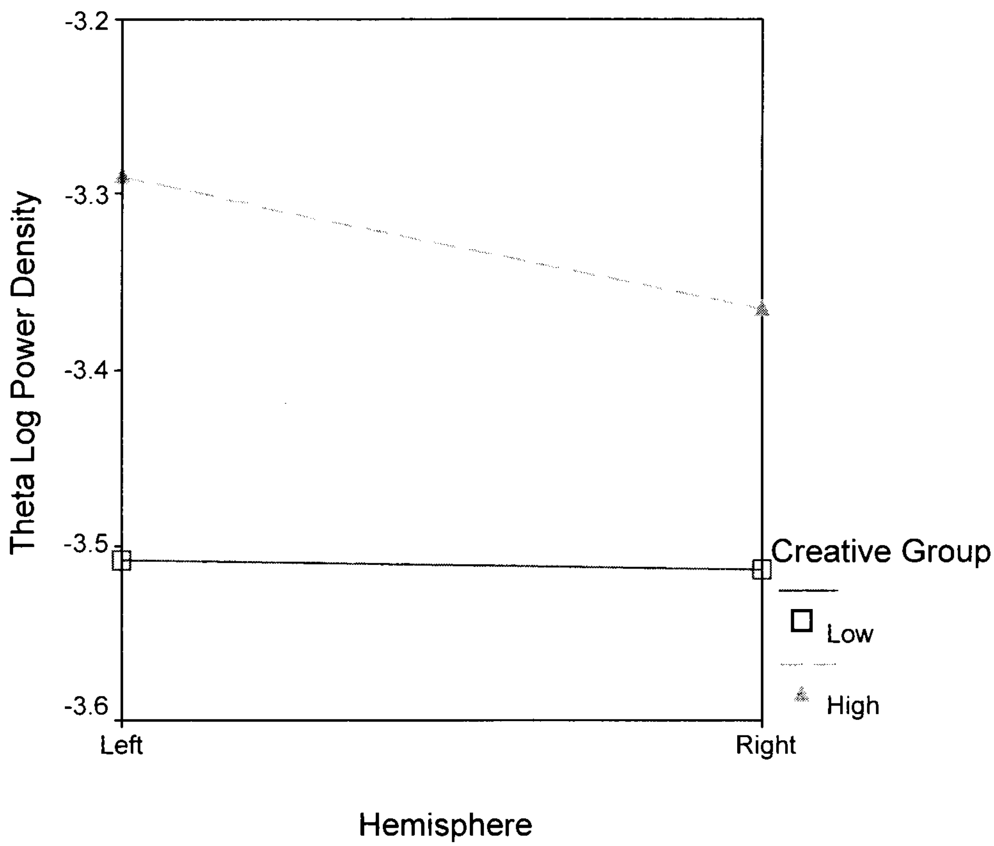
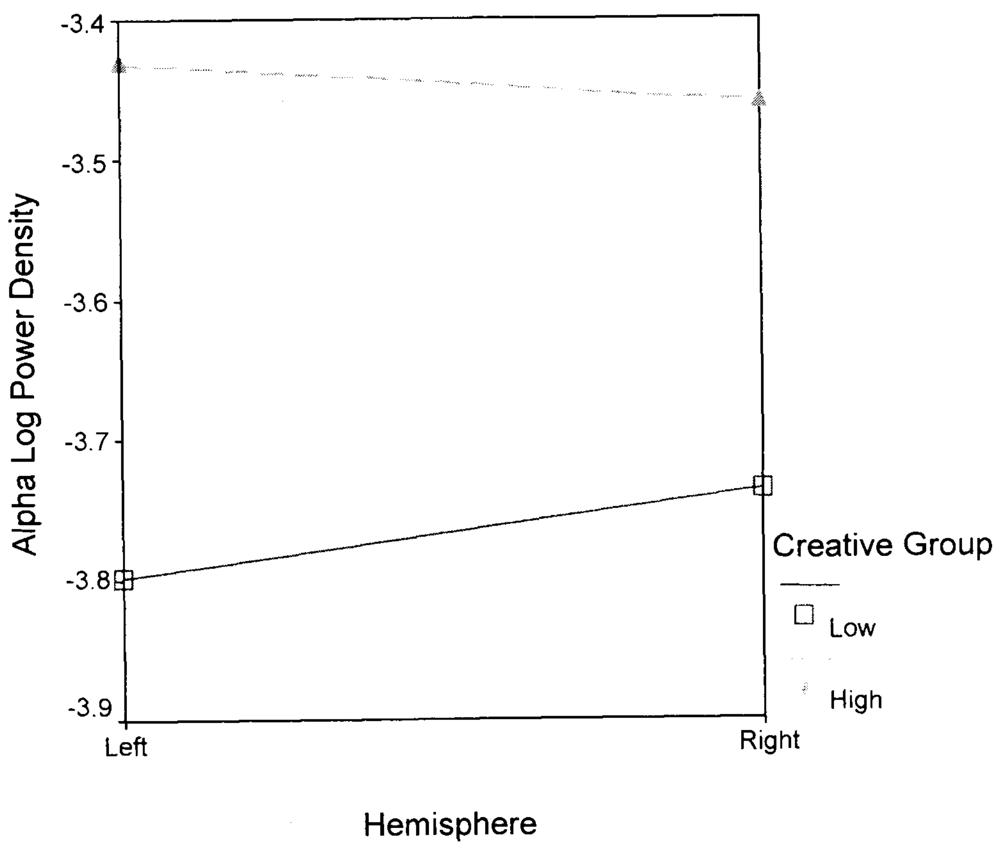


Figure 9

Overall Alpha Log Power Density for Each Hemisphere by CDS Group (High versus Low).



Comparing Figures 10 and 11, it appears that during the creative task, the high CDS group moved in the direction of greater relative right hemisphere activation. In contrast, the low CDS group moved in the direction of greater relative left hemisphere activation.

The next set of analyses examined differences in EEG power density among participants classified as high versus low on the Primary Process minus Secondary Process variable. Tables 44 through 49 summarize these results. None of the critical Task by Hemisphere by Group interactions were significant for any of the frequency bands. The Task by Site by Hemisphere by Primary Process minus Secondary Process Group was significant for the Delta band, but this finding is of questionable significance given the unclear nature of how to interpret power density in the Delta band. No other theoretically relevant effects emerged from these analyses.

Using Primary Process minus Secondary Process scores as the between group variable did not result in any significant Task by Hemisphere by Group interactions. Therefore, no support was found for the hypothesis that grouping participants according to the amount of primary process in their Rorschach responses would serve as a meaningful way to distinguish between those participants that would and would not show the patterns of asymmetric activation predicted by Martindale's theory of creativity.

Finally, a similar set of analyses were conducted using scores on Eysenck's Psychoticism scale to determine if there were any group differences in power density for high and low scorers on the Psychoticism scale. The results are outlined in Tables 50 through 55. No theoretically significant results were evident in these analyses.

Figure 10

Alpha Log Power Density for Each Hemisphere and CDS Group (High versus Low) During Session One Resting Baseline.

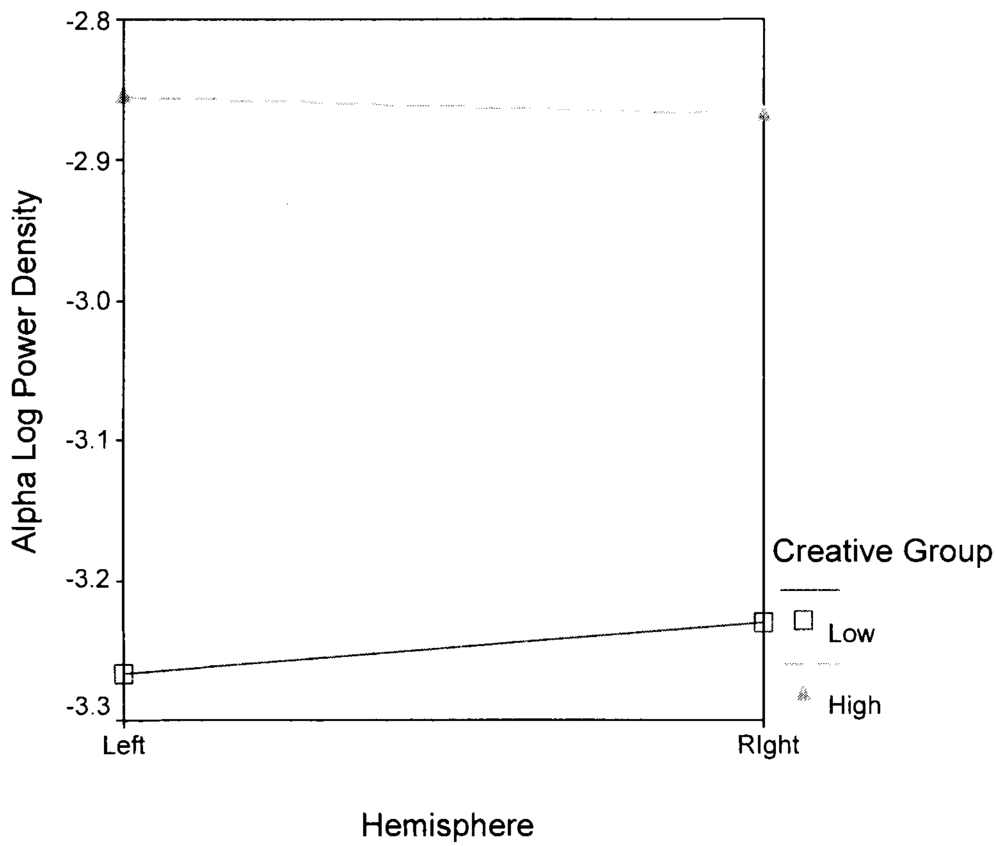


Figure 11

Alpha Log Power Density for Each Hemisphere and CDS Group (High versus Low) During the Creative Task.

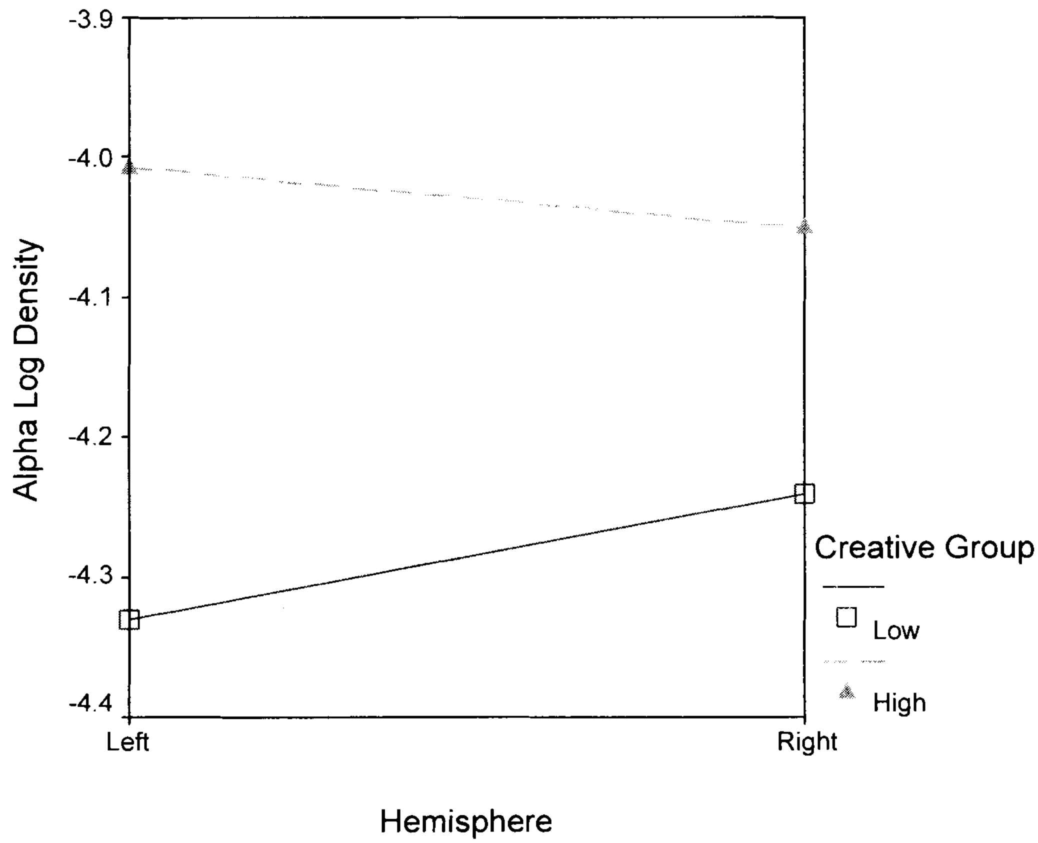


Table 44

Task (Resting versus Creative Task) by Band by Site by Hemisphere by Primary Process Minus Secondary Process (High versus Low).

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 117.79 | 66.36*** |
| Task x PPMSP-HL | 1 | .18 | .10 |
| Error | 66 | 1.78 | |
| Band | 4 | 862.55 | 655.20*** |
| Band x PPMSP-HL | 4 | 2.05 | 1.56 |
| Error | 264 | 1.32 | |
| Site | 2 | 11.73 | 31.78*** |
| Site x PPMSP-HL | 2 | 2.25 | 6.09** |
| Error | 132 | .37 | |
| Hemi | 1 | .20 | 1.33 |
| Hemi x PPMSP-HL | 1 | .34 | 2.23 |
| Error | 66 | .15 | |
| Task x Band | 4 | 44.37 | 115.94*** |
| Task x Band x PPMSP-HL | 4 | .61 | 1.60 |
| Error | 264 | .38 | |
| Task x Site | 2 | 5.62 | 35.07*** |
| Task x Site x PPMSP-HL | 2 | .30 | 1.86 |
| Error | 132 | .16 | |
| Band x Site | 8 | 4.28 | 33.12*** |

Table 44 Continued

| | | | |
|---|---|---|---|
| Band x Site x PPMSP-HL | 8 | .16 | 1.25 |
| Error | 528 | .13 | |
| Task x Band x Site | 8 | .91 | 12.12*** |
| Task x Band x PPMSP-HL | 8 | .04 | .52 |
| Error | 528 | .08 | |
| Task x Hemi | 1 | .00 | .00 |
| Task x Hemi x PPMSP-HL | 1 | .02 | .48 |
| Error | 66 | .03 | |
| Band x Hemi | 4 | .31 | 9.64*** |
| Band x Hemi x PPMSP-HL | 4 | .01 | .17 |
| Error | 264 | .03 | |
| Task x Band x Hemi | 4 | .01 | .51 |
| Task x Band x Hemi x PPMSP-HL | 4 | .01 | .43 |
| Error | 264 | .01 | |
| Site x Hemi | 2 | .04 | .58 |
| Site x Hemi x PPMSP-HL | 2 | .14 | 1.91 |
| Error | 132 | .07 | |
| Task x Site x Hemi | 2 | .00 | .23 |
| Task x Site x Hemi x PPMSP-HL | 2 | .000 | .03 |
| Error | 132 | .02 | |

Table 44 Continued

| | | | |
|---|---|---|---|
| Band x Site x Hemi | 8 | .25 | 9.87*** |
| Band x Site x Hemi x PPMSP-HL | 8 | .01 | .51 |
| Error | 528 | .03 | |
| Task x Band x Site x Hemi | 8 | .02 | 2.42* |
| Task x Hemi x Site x Hemi x PPMSP-HL | 8 | .01 | 1.27 |
| Error | 528 | .01 | |

Note. Task = Creative task versus resting baseline; Band = Frequency band (Delta, Theta, Alpha, Beta1, Beta2); Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PPMSP-HL = Primary Process minus Secondary Process (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 45

Task (Creative Task versus Resting) by Site by Hemisphere by Primary Process Minus Secondary Process (High versus Low) for Delta Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 2.07 | 7.54** |
| Task x PPMSP-HL | 1 | .07 | .26 |
| Error | 66 | .28 | |
| Site | 2 | 14.60 | 146.18*** |
| Site x PPMSP-HL | 2 | .37 | 3.70* |
| Error | 132 | .10 | |
| Hemi | 1 | .00 | .09 |
| Hemi x PPMSP-HL | 1 | .07 | 3.20 |
| Error | 66 | .02 | |
| Task x Site | 2 | .12 | 4.58* |
| Task x Site x PPMSP-HL | 2 | .02 | .71 |
| Error | 132 | .03 | |
| Task x Hemi | 1 | .01 | .83 |
| Task x Hemi x PPMSP-HL | 1 | .00 | .00 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .01 | .85 |
| Site x Hemi x PPMSP-HL | 2 | .00 | .24 |
| Error | 132 | .01 | |
| Task x Site x Hemi | 2 | .00 | .13 |

Table 45 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PPMSP-HL | 2 | .01 | 3.34* |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PPMSP-HL = Primary Process minus Secondary Process (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 46

Task (Creative Task versus Resting) by Site by Hemisphere by Primary Process Minus Secondary Process (High versus Low) for Theta Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 24.49 | 51.10*** |
| Task x PPMSP-HL | 1 | .00 | .00 |
| Error | 66 | .48 | |
| Site | 2 | 5.92 | 30.52*** |
| Site x PPMSP-HL | 2 | .83 | 4.27* |
| Error | 132 | .19 | |
| Hemi | 1 | .32 | 8.36** |
| Hemi x PPMSP-HL | 1 | .04 | .97 |
| Error | 66 | .04 | |
| Task x Site | 2 | .90 | 38.22*** |
| Task x Site x PPMSP-HL | 2 | .03 | 1.13 |
| Error | 132 | .02 | |
| Task x Hemi | 1 | .00 | .01 |
| Task x Hemi x PPMSP-HL | 1 | .00 | .10 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .49 | 26.14*** |
| Site x Hemi x PPMSP-HL | 2 | .01 | .59 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .03 | 7.65** |

Table 46 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PPMSP-HL | 2 | .00 | .52 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PPMSP-HL = Primary Process minus Secondary Process (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 47

Task (Creative Task versus Resting) by Site by Hemisphere by Primary Process Minus Secondary Process (High versus Low) for Alpha Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 247.21 | 182.75*** |
| Task x PPMSP-HL | 1 | .95 | .70 |
| Error | 66 | 1.35 | |
| Site | 2 | 5.58 | 30.67*** |
| Site x PPMSP-HL | 2 | 1.21 | 6.63** |
| Error | 132 | .18 | |
| Hemi | 1 | .07 | 1.40 |
| Hemi x PPMSP-HL | 1 | .05 | .92 |
| Error | 66 | .05 | |
| Task x Site | 2 | 3.80 | 54.99*** |
| Task x Site x PPMSP-HL | 2 | .21 | 3.02 |
| Error | 132 | .07 | |
| Task x Hemi | 1 | .01 | .52 |
| Task x Hemi x PPMSP-HL | 1 | .04 | 2.32 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .00 | .02 |
| Site x Hemi x PPMSP-HL | 2 | .03 | 1.26 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .01 | 1.56 |

Table 47 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PPMSP-HL | 2 | .00 | .40 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PPMSP-HL = Primary Process minus Secondary Process (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 48

Task (Creative Task versus Resting) by Site by Hemisphere by Primary Process Minus Secondary Process (High versus Low) for Beta 1 Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 17.42 | 34.02*** |
| Task x PPMSP-HL | 1 | .24 | .47 |
| Error | 66 | .51 | |
| Site | 2 | .14 | .71 |
| Site x PPMSP-HL | 2 | .45 | 2.27 |
| Error | 132 | .20 | |
| Hemi | 1 | .07 | .75 |
| Hemi x PPMSP-HL | 1 | .07 | .70 |
| Error | 66 | .09 | |
| Task x Site | 2 | 1.42 | 10.06*** |
| Task x Site x PPMSP-HL | 2 | .18 | 1.29 |
| Error | 132 | .14 | |
| Task x Hemi | 1 | .01 | .23 |
| Task x Hemi x PPMSP-HL | 1 | .00 | .11 |
| Error | 66 | .02 | |
| Site x Hemi | 2 | .13 | 2.28 |
| Site x Hemi x PPMSP-HL | 2 | .05 | .77 |
| Error | 132 | .05 | |
| Task x Site x Hemi | 2 | .02 | 1.23 |

Table 48 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PPMSP-HL | 2 | .01 | .71 |
| Error | 132 | .01 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PPMSP-HL = Primary Process minus Secondary Process (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 49

Task (Creative Task versus Resting) by Site by Hemisphere by Primary Process Minus Secondary Process (High versus Low) for Beta 2 Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 4.07 | 5.92* |
| Task x PPMSP-HL | 1 | 1.38 | 2.01 |
| Error | 66 | .68 | |
| Site | 2 | 2.59 | 12.37*** |
| Site x PPMSP-HL | 2 | .04 | .177 |
| Error | 132 | .21 | |
| Hemi | 1 | 1.00 | 12.41** |
| Hemi x PPMSP-HL | 1 | .15 | 1.84 |
| Error | 66 | .08 | |
| Task x Site | 2 | 2.99 | 15.07*** |
| Task x Site x PPMSP-HL | 2 | .02 | .09 |
| Error | 132 | .19 | |
| Task x Hemi | 1 | .01 | .29 |
| Task x Hemi x PPMSP-HL | 1 | .00 | .00 |
| Error | 66 | .03 | |
| Site x Hemi | 2 | .42 | 6.75** |
| Site x Hemi x PPMSP-HL | 2 | .10 | 1.70 |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.12 |

Table 49 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PPMSP-HL | 2 | .01 | .686 |
| Error | 132 | .01 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PPMSP-HL = Primary Process minus Secondary Process Group (High versus Low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

## EEG Asymmetry, Mood, and Personality

The final component of the present study examined the relationships between EEG asymmetry, mood, and personality. Following this, the effects of happy and sad mood inductions on cognition and EEG asymmetry were examined.

### Frontal EEG Asymmetry, Mood, and Personality

It was predicted that frontal EEG asymmetry would correlate with mood and personality such that relatively greater positive asymmetry values (greater left hemisphere activation) in the frontal lobes would correlate positively with measures of positive affect, behavioral activation, trait pleasure, and extraversion. Conversely, it was predicted that relatively greater right frontal hemisphere activation would correlate positively with measures of negative affect, introversion and behavioral inhibition. Parietal EEG asymmetry was predicted to be uncorrelated with any of the mood or personality measures, although this possibility was examined because some previous research has found a relationship between relatively greater right parietal activation and anxiety (Heller, 1990a).

Two sets of analyses were conducted to examine the relationship between EEG asymmetry and the mood and personality variables. First, correlations between the asymmetry values and the mood and personality variables were computed for each frequency band individually using the session one baseline data. This set of analyses was carried out using session one resting EEG asymmetry data because more participants ($N = 68$) were available for these analyses. The second set of analyses used the averaged resting EEG asymmetry data from both sessions ($N = 57$) in a split-plot MANOVA design.

Table 50

Task (Resting versus Creative Task) by Band by Site by Hemisphere by Psychoticism Group (High versus Low).

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 118.10 | 66.67*** |
| Task x PSY-HL | 1 | .43 | .24 |
| Error | 66 | 1.75 | |
| Band | 4 | 861.33 | 642.69*** |
| Band x PSY-HL | 4 | .49 | .36 |
| Error | 264 | 1.32 | |
| Site | 2 | 11.84 | 29.78*** |
| Site x PSY-HL | 2 | .37 | .92 |
| Error | 132 | .37 | |
| Hemi | 1 | .19 | 1.23 |
| Hemi x PSY-HL | 1 | .46 | 3.05 |
| Error | 66 | .15 | |
| Task x Band | 4 | 44.20 | 113.28*** |
| Task x Band x PSY-HL | 4 | .12 | .31 |
| Error | 264 | .28 | |
| Task x Site | 2 | 5.62 | 35.36*** |
| Task x Site x PSY-HL | 2 | .37 | 2.31 |
| Error | 132 | .16 | |
| Band x Site | 8 | 4.33 | 34.31*** |

Table 50 Continued

| | | | |
|---|---|---|---|
| Band x Site x PSY-HL | 8 | .35 | 2.80** |
| Error | 528 | .13 | |
| Task x Band x Site | 8 | .90 | 12.12*** |
| Task x Band x PSY-HL | 8 | .06 | .83 |
| Error | 528 | .08 | |
| Task x Hemi | 1 | .00 | .01 |
| Task x Hemi x PSY-HL | 1 | .06 | 1.79 |
| Error | 66 | .03 | |
| Band x Hemi | 4 | .31 | 9.78*** |
| Band x Hemi x PSY-HL | 4 | .06 | 1.74 |
| Error | 264 | .03 | |
| Task x Band x Hemi | 4 | .01 | .54 |
| Task x Band x Hemi x PSY-HL | 4 | .02 | 1.56 |
| Error | 264 | .01 | |
| Site x Hemi | 2 | .05 | .67 |
| Site x Hemi x PSY-HL | 2 | .22 | 3.08* |
| Error | 132 | .07 | |
| Task x Site x Hemi | 2 | .00 | .24 |
| Task x Site x Hemi x PSY-HL | 2 | .01 | .35 |
| Error | 132 | .02 | |
| Band x Site x Hemi | 8 | .25 | 9.96*** |
| Band x Site x Hemi x PSY-HL | 8 | .02 | .92 |

Table 50 Continued

| | | | |
|---|---|---|---|
| Error | 528 | .03 | |
| Task x Band x Site x Hemi | 8 | .02 | 2.10* |
| Task x Hemi x Site x Hemi x PSY-HL | 8 | .01 | .87 |
| Error | 528 | .01 | |

Note. Task = Creative task versus resting baseline; Band = Frequency band (Delta, Theta. Alpha, Beta1, Beta2); Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PSY-HL = Psychoticism (high versus low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 51

Task (Creative Task versus Resting) by Site by Hemisphere by Psychoticism (High versus Low) for Delta Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 2.10 | 7.69** |
| Task x PSY-HL | 1 | .15 | .56 |
| Error | 66 | .28 | |
| Site | 2 | 14.75 | 151.09*** |
| Site x PSY-HL | 2 | .52 | 5.32** |
| Error | 132 | .10 | |
| Hemi | 1 | .00 | .07 |
| Hemi x PSY-HL | 1 | .05 | 2.36 |
| Error | 66 | .02 | |
| Task x Site | 2 | .12 | 4.57* |
| Task x Site x PSY-HL | 2 | .02 | .54 |
| Error | 132 | .03 | |
| Task x Hemi | 1 | .01 | .81 |
| Task x Hemi x PSY-HL | 1 | .00 | .12 |
| Error | 66 | .03 | |
| Site x Hemi | 2 | .01 | .84 |
| Site x Hemi x PSY-HL | 2 | .01 | .96 |
| Error | 312 | .01 | |
| Task x Site x Hemi | 2 | .00 | .11 |

Table 51 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PSY-HL | 2 | .00 | .73 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PSY-HL = Psychoticism (High versus Low). N = 68.

* $p < .05$, ** $p < .01$. *** $p < .001$.

Table 52

Task (Creative Task versus Resting) by Site by Hemisphere by Psychoticism (High versus Low) for Theta Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 24.54 | 51.30*** |
| Task x PSY-HL | 1 | .06 | .12 |
| Error | 66 | .48 | |
| Site | 2 | 6.04 | 30.77*** |
| Site x PSY-HL | 2 | .69 | 3.52* |
| Error | 132 | .19 | |
| Hemi | 1 | .32 | 8.60** |
| Hemi x PSY-HL | 1 | .05 | 1.35 |
| Error | 66 | .04 | |
| Task x Site | 2 | .90 | 37.58*** |
| Task x Site x PSY-HL | 2 | .00 | .16 |
| Error | 132 | .02 | |
| Task x Hemi | 1 | .00 | .02 |
| Task x Hemi x PSY-HL | 1 | .01 | .47 |
| Error | 66 | .01 | |
| Site x Hemi | 2 | .48 | 26.04*** |
| Site x Hemi x PSY-HL | 2 | .02 | 1.15 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .03 | 7.64*** |

Table 52 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PSY-HL | 2 | .01 | 2.89 |
| Error | 132 | .00 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PSY-HL = Psychoticism (High versus Low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 53

Task (Creative Task versus Resting) by Site by Hemisphere by Psychoticism (High versus Low) for Alpha Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 246.84 | 180.61*** |
| Task x PSY-HL | 1 | .03 | .02 |
| Error | 66 | 1.35 | |
| Site | 2 | 5.63 | 28.46*** |
| Site x PSY-HL | 2 | .17 | .87 |
| Error | 132 | .18 | |
| Hemi | 1 | .07 | 1.38 |
| Hemi x PSY-HL | 1 | .00 | .00 |
| Error | 66 | .05 | |
| Task x Site | 2 | 3.80 | 52.70*** |
| Task x Site x PSY-HL | 2 | .01 | .14 |
| Error | 132 | .07 | |
| Task x Hemi | 1 | .01 | .51 |
| Task x Hemi x PSY-HL | 1 | .00 | .02 |
| Error | 66 | .02 | |
| Site x Hemi | 2 | .00 | .02 |
| Site x Hemi x PSY-HL | 2 | .03 | 1.31 |
| Error | 132 | .02 | |
| Task x Site x Hemi | 2 | .01 | 1.54 |

Table 53 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PSY-HL | 2 | .00 | .30 |
| Error | 132 | .01 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PSY-HL = Psychoticism (High versus Low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 54

Task (Creative Task versus Resting) by Site by Hemisphere by Psychoticism (High versus Low) for Beta 1 Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 17.45 | 33.89*** |
| Task x PSY-HL | 1 | .04 | .08 |
| Error | 66 | .52 | |
| Site | 2 | .14 | .68 |
| Site x PSY-HL | 2 | .01 | .02 |
| Error | 132 | .21 | |
| Hemi | 1 | .06 | .68 |
| Hemi x PSY-HL | 1 | .39 | 4.34* |
| Error | 66 | .08 | |
| Task x Site | 2 | 1.40 | 10.07*** |
| Task x Site x PSY-HL | 2 | .28 | 1.97 |
| Error | 66 | .14 | |
| Task x Hemi | 1 | .01 | .20 |
| Task x Hemi x PSY-HL | 1 | .05 | 2.11 |
| Error | 66 | .02 | |
| Site x Hemi | 2 | .14 | 2.36 |
| Site x Hemi x PSY-HL | 2 | .06 | 1.08 |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.22 |

Table 54 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PSY-HL | 2 | .00 | .15 |
| Error | 132 | .02 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PSY-HL = Psychoticism (High versus Low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 55

Task (Creative Task versus Resting) by Site by Hemisphere by Psychoticism (High versus Low) for Beta 2 Power Density Values.

| Source | df | MS | F |
|---|---|---|---|
| Task | 1 | 3.97 | 5.68* |
| Task x PSY-HL | 1 | .62 | 0.89 |
| Error | 66 | .70 | |
| Site | 2 | 2.62 | 12.81*** |
| Site x PSY-HL | 2 | .40 | 1.94 |
| Error | 132 | .20 | |
| Hemi | 1 | .97 | 12.18** |
| Hemi x PSY-HL | 1 | .19 | 2.42 |
| Error | 66 | .08 | |
| Task x Site | 2 | 3.01 | 15.45*** |
| Task x Site x PSY-HL | 2 | .31 | 1.60 |
| Error | 66 | .20 | |
| Task x Hemi | 1 | .01 | .36 |
| Task x Hemi x PSY-HL | 1 | .09 | 2.87 |
| Error | 66 | .03 | |
| Site x Hemi | 2 | .43 | 7.08*** |
| Site x Hemi x PSY-HL | 2 | .19 | 3.12* |
| Error | 132 | .06 | |
| Task x Site x Hemi | 2 | .02 | 1.17 |

Table 55 Continued

| | | | |
|---|---|---|---|
| Task x Site x Hemi x PSY-HL | 2 | .02 | .91 |
| Error | 132 | .02 | |

Note. Task = Creative task versus resting baseline; Site = Electrode site (Frontal, Central Parietal); Hemi = Hemisphere (Left, Right); PSY-HL = Psychoticism (High versus Low). N = 68.

* $p < .05$, ** $p < .01$, *** $p < .001$.

The correlation analyses revealed very few significant correlations between EEG asymmetry and the mood and personality variables. The results are presented in Appendix S. The correlations that did emerge must be interpreted with caution due to the number of correlations and the consequent increase in the probability of a Type I error. A total of 240 correlations were computed. Therefore, 12 correlations would be expected by chance at $p = .05$. Using a .01 significance level as the criterion for statistical significance, only one correlation can be regarded as potentially meaningful.

The findings for the Alpha band suggested that EEG asymmetry in the parietal region was significantly correlated with a measure of trait anxiety. Specifically, greater relative left hemisphere parietal activation was associated with higher levels of trait anxiety. This finding is opposite to what was predicted based on Davidson's model of the relationship between frontal EEG asymmetry and affective style. Figure 12 illustrates that the high trait anxiety group displayed greater log density alpha power in the right hemisphere than the left. (Remember that Alpha power is inversely related to activation.)

As Tables S.4 and S.5 in Appendix S indicate, there were no relationships between either Beta band asymmetry and mood or personality with the exception of a negative correlation between Beta 1 frontal asymmetry and the PAD Temperament Pleasure and the PAD Emotion Arousal scale. In addition, the findings for the Delta band are entirely nonsignificant, with the exception of a positive correlation between central Delta asymmetry and behavioral inhibition. The results concerning the Theta band indicate a possible relationship between extraversion and frontal EEG such that higher scores on extraversion were correlated with greater relative right hemisphere activation. Central Theta asymmetry correlated with behavioral activation and the PAD

Temperament Arousal scale such that higher scores on these variables were associated with greater relative right frontal activation. All of these correlations were significant only at the .05 level and are therefore not described in more detail due to the likelihood of being the result of chance alone.

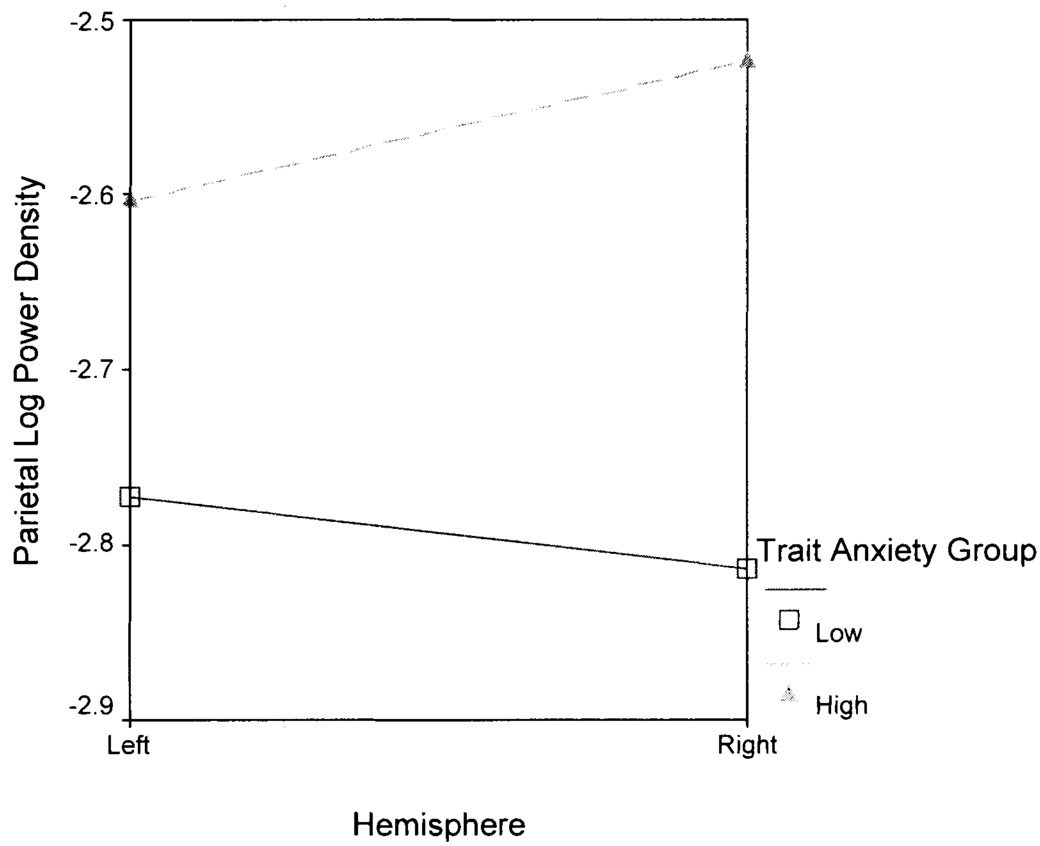
In addition to these correlations, a series of split-plot MANOVAs were conducted using median splits to define high and low groups on the emotion and personality measures. The within group variables were Band (Delta, Theta, Alpha, Beta 1, Beta 2), Site (Frontal, Central, Parietal), and Hemisphere (Left, Right). The averaged log density values were used instead of the values only from session one under the assumption that the averaged values may better represent an individual's "true" asymmetry status. Only one variable resulted in a significant interaction involving Hemisphere. Table 56 summarizes the results using high and low groups on the negative affect scale from the Positive and Negative Affect Scale.

Table 56 shows that there was a significant Band by Site by Hemisphere by Negative Affect group interaction. To understand further this significant interaction, follow-up analysis of variance tests were computed to examine each band individually. The results (not shown) indicated that the parietal locations for the Beta 1 and Beta 2 bands were responsible for this interaction. Therefore, contrary to predictions, group differences in negative affect scores were not significantly related to hemispheric asymmetry in frontal locations.

Based on previous research finding that emotion/asymmetry relationships may depend on whether or not a person's asymmetry values are stable over time (e.g., Davidson et al., 1995), this possibility was examined in the present study.

Figure 12

Parietal Alpha Log Density Power Values for Low and High Trait Anxiety Groups.



The interaction between stability group and emotion/personality variables was explored for each band and each site in a series of split-plot analyses using stability group and high versus low emotion/personality groups (median split) as between subject variables and log power density for each site within each band as the within subject variable. None of these analyses revealed any significant effects for stability group and are therefore not described further.

Effectiveness of the Mood Induction Procedure

The first step in evaluating the effectiveness of the mood induction was to inspect the mood scores for each participant to determine if change occurred in the predicted directions. One participant's mood scores did not change at all - one male from the happy mood induction. This participant was excluded from the following analyses because of his non-responsiveness to the mood induction procedure. Thus, 56 participants were included in the following analyses (27 happy, 29 sad).

Separate repeated measures analysis of variance were conducted to examine the effectiveness of the mood induction procedure using positive affect, negative affect, pleasure, arousal, and dominance scores as the dependent variables. Tables 57 through 61 (with accompanying figures) summarize the results of the effect of the mood induction on the mood state variables.

The figures depicting the pre- and post-mood scores clearly show that the sad mood induction was more effect in changing mood scores than the happy mood induction. Follow-up paired samples t-tests were conducted to determine which mood variables changed significantly within the happy mood induction condition. These results are shown in Table 62.

Table 56

Split-Plot Multivariate Analysis of Variance for Negative Affect Group (High versus Low) by Frequency Band, Electrode Site, and Hemisphere for the Average Power Density Across Both Sessions.

| Source | df | MS | F |
|---|---|---|---|
| Band | 4 | 466.72 | 472.13*** |
| Band x Negative Affect | 4 | .25 | .25 |
| Error | 216 | .98 | |
| Site | 2 | 4.44 | 13.15*** |
| Site x Negative Affect | 2 | .69 | 2.05 |
| Error | 108 | .33 | |
| Hemi | 1 | .06 | 1.16 |
| Hemi x Negative Affect | 1 | .12 | 2.10 |
| Error | 54 | .04 | |
| Band x Site | 8 | 3.69 | 50.72*** |
| Band x Site x Negative Affect | 8 | .09 | 1.26 |
| Error | 432 | .08 | |
| Band x Hemi | 4 | .11 | 8.23*** |
| Band x Hemi x Negative Affect | 4 | .00 | .22 |
| Error | 216 | .01 | |
| Site x Hemi | 2 | .01 | .20 |
| Site x Hemi x Negative Affect | 2 | .10 | 3.58* |
| Error | 108 | .03 | |

Table 56 Continued

| | | | |
|---|---|---|---|
| Band x Site x Hemi | 8 | .13 | 12.77*** |
| Band x Site x Hemi x Negative Affect | 8 | .04 | 3.44*** |
| Error | 432 | .01 | |

Note. Band = Frequency Band (Delta, Theta, Alpha, Beta1, Beta2); Negative Affect = Negative Affect scale of the Positive and Negative Affect Scale (High versus Low); Site = Cortical region (Frontal, Central, Parietal); Hemi = Hemisphere (Left, Right). N = 57.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 57

Effect of Mood on Positive Affect.

| Source | df | MS | F |
|---|---|---|---|
| Time | 1 | 19.51 | 1.82 |
| Mood x Time | 1 | 95.16 | 8.87** |
| Error | 54 | 10.73 | |

Note. Time = Time 1 (pre-mood induction) versus Time 2 (post-mood induction).

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 13

Effect of Mood on Positive Affect.

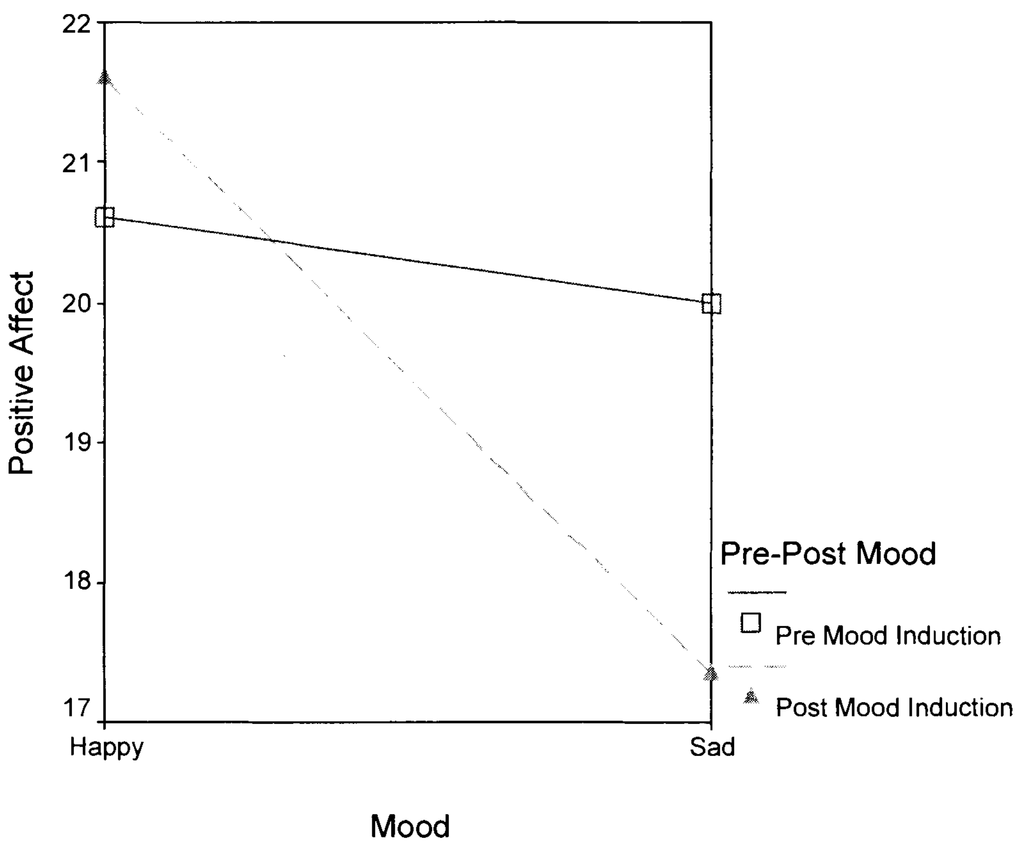


Table 58

Effect of Mood on Pleasure Scores.

| Source | Df | MS | F |
|---|---|---|---|
| Time | 1 | 323.82 | 34.26*** |
| Mood x Time | 1 | 666.21 | 70.48*** |
| Error | 54 | 9.45 | |

Note. Pleasure = Pleasure scale from the short form of the PAD Emotion Scale.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 14

Effect of Mood on Pleasure Scores.

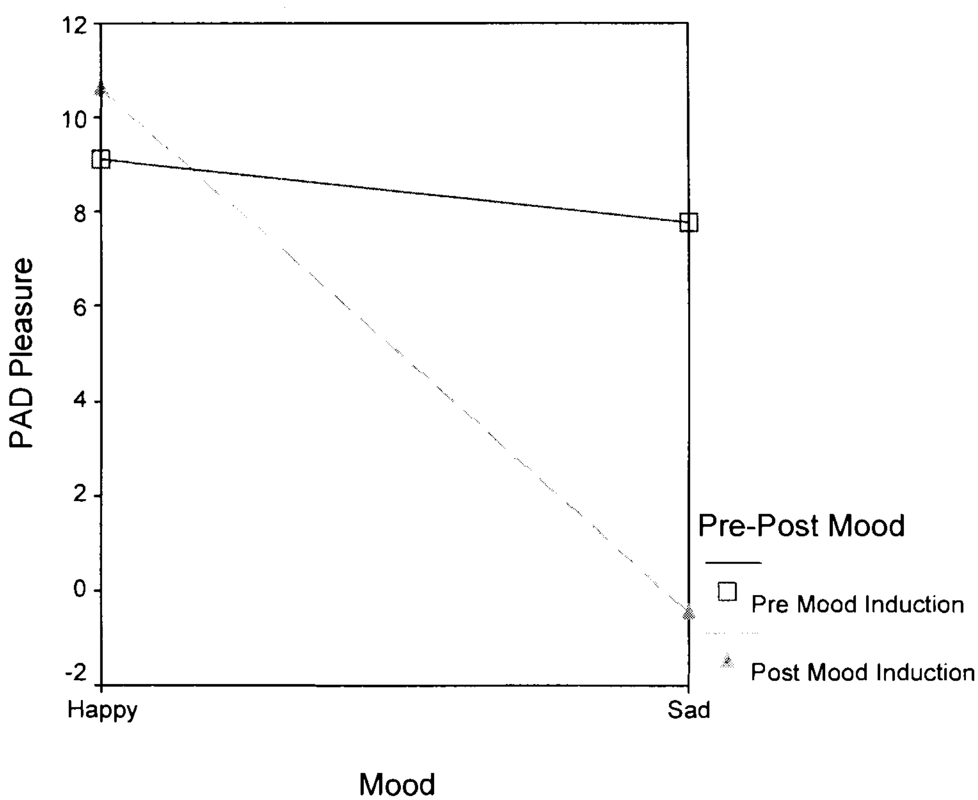


Table 59

Effect of Mood on Negative Affect.

| Source | df | MS | F |
|---|---|---|---|
| Time | 1 | 166.09 | 20.58*** |
| Mood x Time | 1 | 325.24 | 40.30*** |
| Error | 54 | 8.07 | |

Note. Negative Affect = Negative affect scale from the Positive and Negative Affect Scale; Time = Pre-Mood versus Post-Mood Induction.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 15

Effect of Mood on Negative Affect.

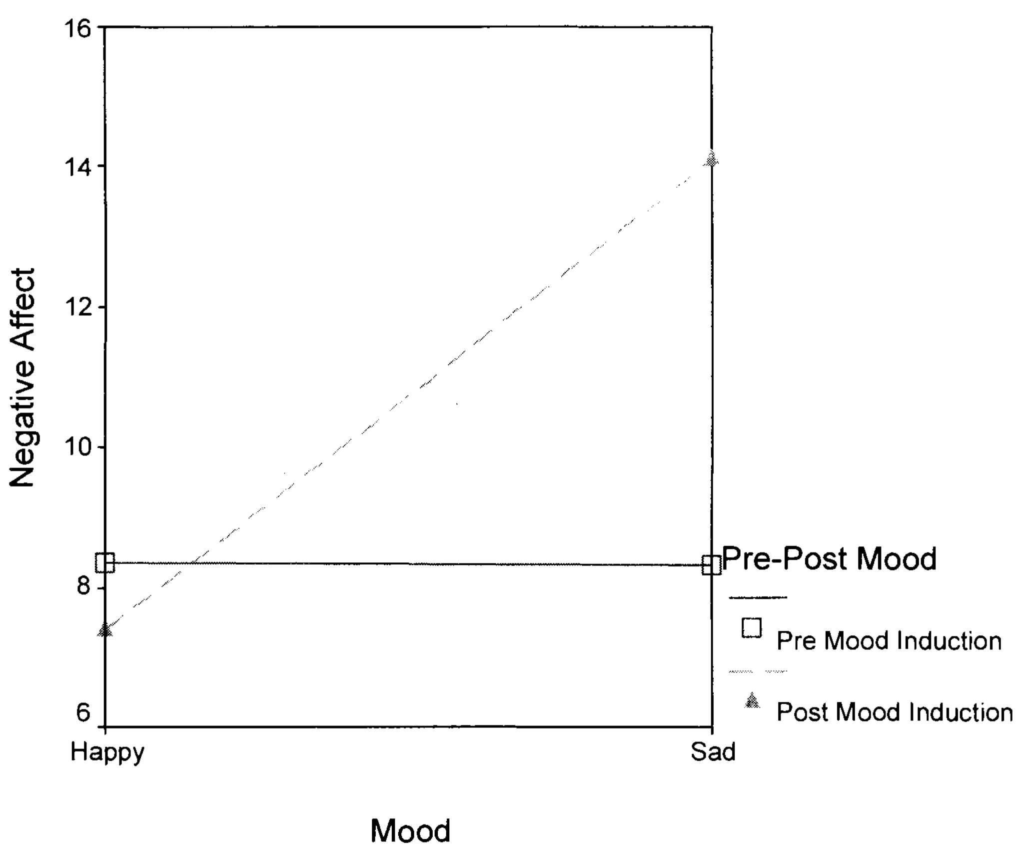


Table 60

Effect of Mood on Arousal Emotion Scores.

| Source | df | MS | F |
|---|---|---|---|
| Time | 1 | 1271.51 | 50.10*** |
| Mood x Time | 1 | 42.14 | 1.66 |
| Error | 54 | 25.38 | |

Note. Arousal = Arousal scale from the short form of the PAD Emotion Scales: Time = Pre-Mood versus Post-Mood Induction.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 16

Effect of Mood on Arousal Scores.

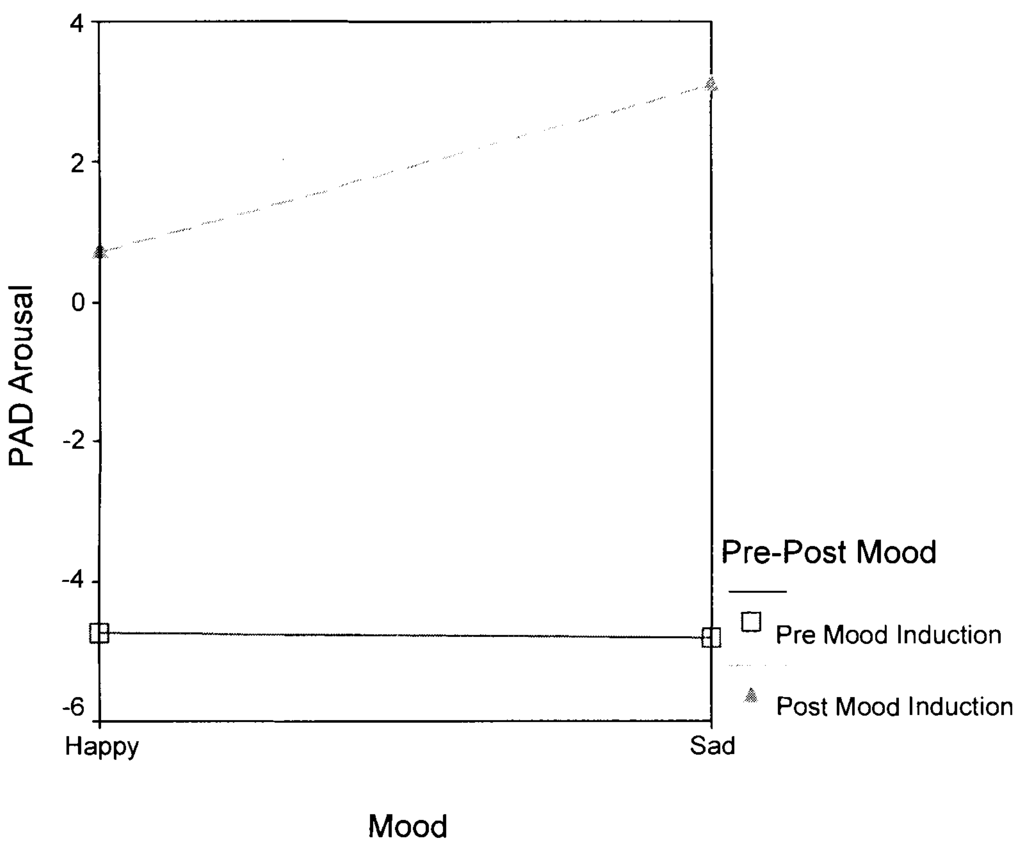


Table 61

Effect of Mood on Dominance Scores.

| Source | df | MS | F |
|---|---|---|---|
| Time | 1 | 5.25 | .43 |
| Mood x Time | 1 | 6.13 | .50 |
| Error | 54 | 12.34 | |

Note. Time = Pre-Mood versus Post-Mood Induction.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 17

Effect of Mood on Dominance Scores.

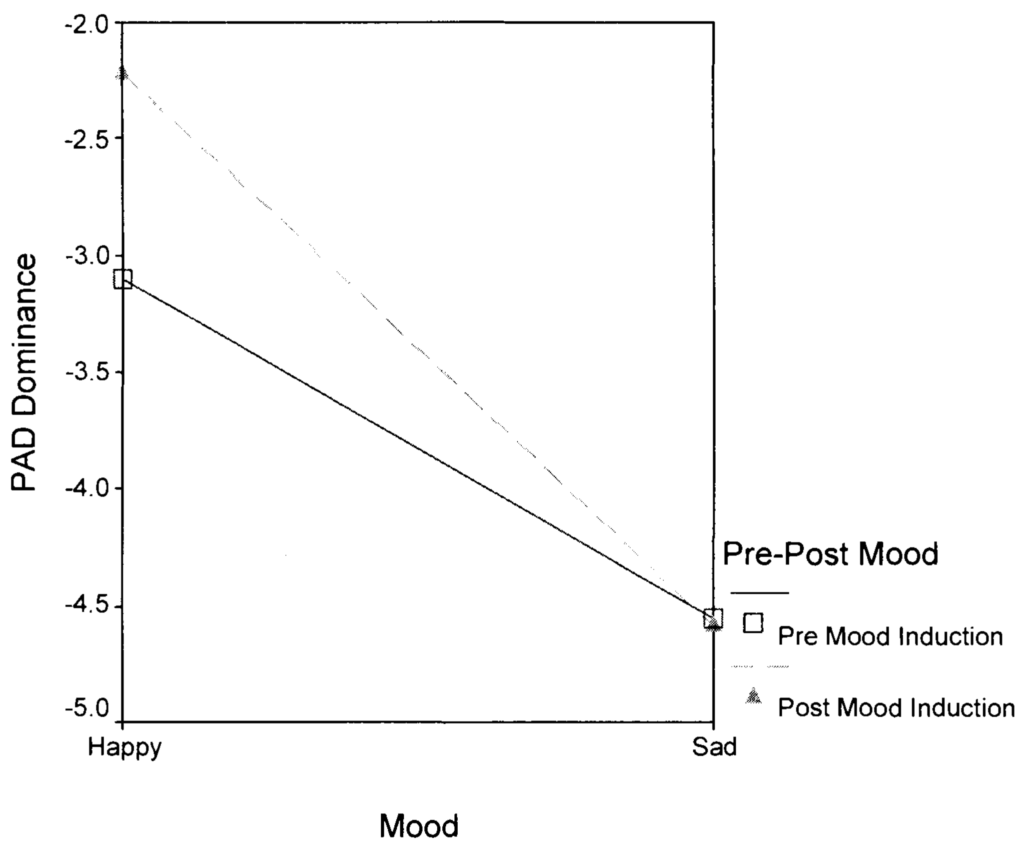


Table 62

Paired Samples T-Tests for the Happy Mood Condition.

| Mood Measure | df | t |
|---|---|---|
| Pre/Post Positive Affect | 26 | -1.25 |
| Pre/Post Negative Affect | 26 | 3.19** |
| Pre/Post Pleasure | 26 | -3.82** |
| Pre/Post Arousal | 26 | -4.09*** |
| Pre/Post Dominance | 26 | -.88 |

Note. Pleasure = PAD Pleasure Emotion scale; Arousal = PAD Arousal Emotion scale; Dominance = PAD Dominance Emotion scale.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Considering only the happy mood induction, the results of the paired sample t-tests indicated that the positive affect and the dominance scores did not change within this condition. However, the negative affect, pleasure, and arousal scales did change significantly as a result of the happy mood induction.

Summarizing these analyses, it is clear the sad mood induction was effective. Consistent with previous research (Westerman et al., 1996), it appears that a sad and/or negative mood is more readily induced than a positive one, although one cannot rule out that the sad mood induction may have simply been more potent in the present study. In addition, the effect of Time on the Arousal scores showed that both mood inductions produced an increase in general level of emotional arousal. This may be due in part because the participants were instructed to sit in a relaxed state while the baseline EEG recordings were made at the beginning of the testing session.

Effect of Mood on Cognition

Based on Bartolic et al's (1999) study, it was predicted that happy and sad mood inductions would influence cognitive functioning such that the happy mood induction would increase verbal fluency and decrease figural fluency and that the sad mood induction would increase figural fluency and decrease verbal fluency.

Repeated measures analysis of variance was conducted to examine the effects of mood on verbal and figural fluency. Table 63 shows the results of these analyses for verbal fluency and Table 64 shows the results of these analyses for figural fluency. Figure 18 depicts the pre and post-mood induction verbal fluency means and Figure 19 depicts the pre and post-mood induction figural fluency means.

These analyses showed that neither mood procedure significantly altered either fluency measure. However, as shown in Figure 18, the direction of change in verbal fluency scores was consistent with predictions. Figure 19 shows that figural fluency increased significantly (by about two points) following both moods and most likely reflects a practice effect.

Effect of Mood on EEG Asymmetry

The final hypothesis in this component of the study predicted that happy and sad mood inductions would cause changes in EEG asymmetry (compared to pre-mood asymmetry) such that happy mood induction would cause shifts toward greater left-hemisphere activation and sad moods would cause shifts toward greater right-hemisphere activation. Repeated measures analysis of variance was conducted to examine the effects of mood on EEG asymmetry. Table 65 summarizes these results.

Table 63

Effect of Mood on Verbal Fluency Scores.

| Source | df | MS | F |
|---|---|---|---|
| Time | 1 | .17 | .06 |
| Mood x Time | 1 | 3.54 | 1.16 |
| Error | 54 | 3.04 | |

Note. Time = Pre-Mood versus Post-Mood Induction.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 18

Effect of Mood on Verbal Fluency.

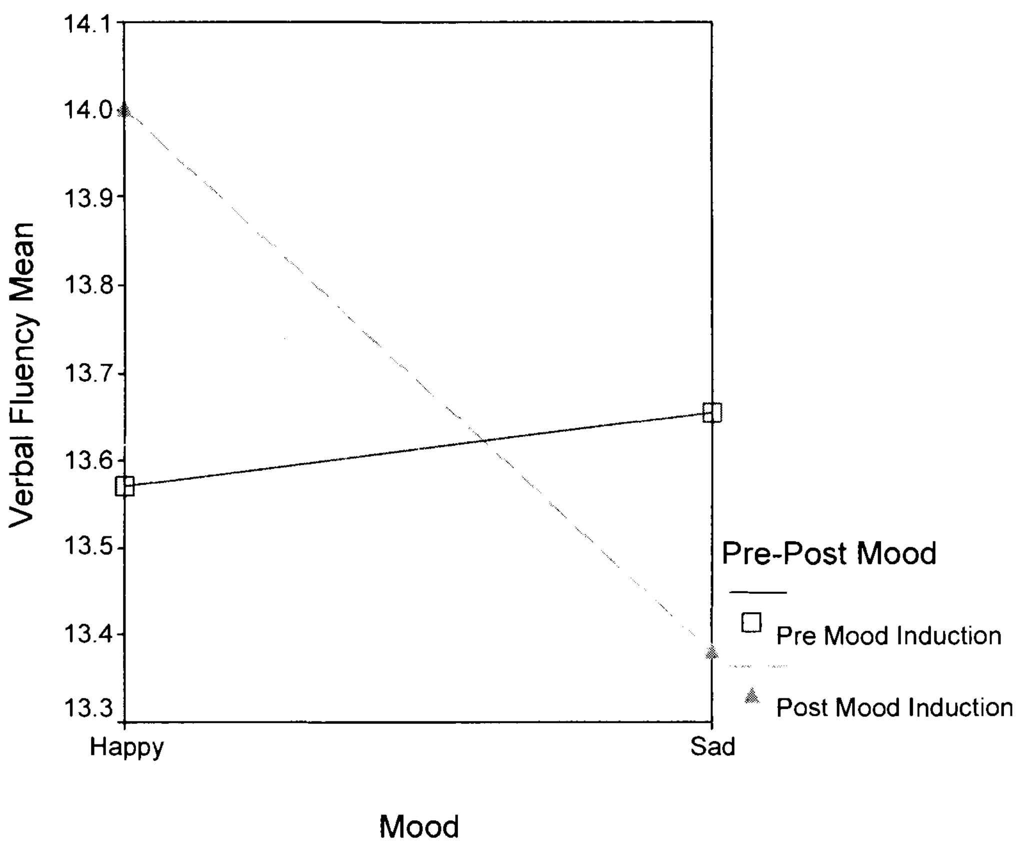


Table 64

Effect of Mood on Figural Fluency Scores.

| Source | df | MS | F |
|---|---|---|---|
| Time | 1 | 82.17 | 19.75*** |
| Mood x Time | 1 | 2.59 | .62 |
| Error | 54 | 4.16 | |

Note. Time = Pre-Mood versus Post-Mood Induction.

* *p* < .05, ** *p* < .01, *** *p* <.001.

Figure 19

Effect of Mood on Figural Fluency Scores.

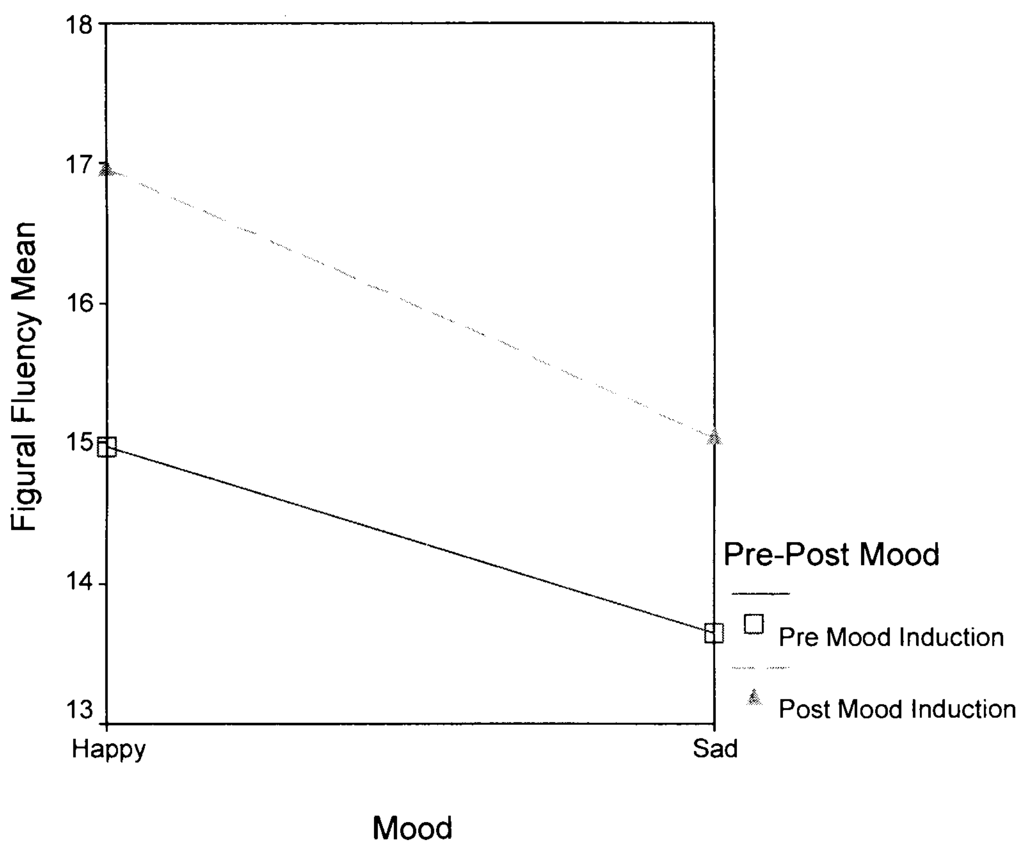


Table 65

Repeated Measures Multivariate Analysis of Variance for Mood (Happy or Sad) by Time (Pre-mood induction versus Post-mood induction) by Frequency Band by Site by Hemisphere.

| Source | df | MS | F |
|---|---|---|---|
| TIME | 1 | 7.80 | 4.28* |
| TIME x MOOD | 1 | .00 | .00 |
| Error | 54 | 1.02 | |
| BAND | 4 | 934.08 | 470.35*** |
| BAND x MOOD | 4 | .45 | .23 |
| Error | 216 | 2.04 | |
| SITE | 2 | 8.52 | 12.68*** |
| SITE x MOOD | 2 | .98 | 1.45 |
| Error | 108 | .76 | |
| HEMI | 1 | .04 | .45 |
| HEMI x MOOD | 1 | .72 | 8.95** |
| Error | 54 | .10 | |
| TIME x BAND | 4 | .88 | 2.64* |
| TIME x BAND x MOOD | 4 | .58 | 1.73 |
| Error | 216 | .31 | |
| TIME x SITE | 2 | .14 | 1.40 |
| TIME x SITE x MOOD | 2 | .27 | 2.65 |
| Error | 108 | .11 | |

Table 65 Continued

| | | | |
|---|---|---|---|
| BAND x SITE | 8 | 7.53 | 52.13*** |
| BAND x SITE x MOOD | 8 | .29 | 1.99* |
| Error | 432 | .21 | |
| TIME x BAND x SITE | 8 | .13 | 1.51 |
| TIME x BAND x SITE x MOOD | 8 | .08 | .91 |
| Error | 432 | .07 | |
| TIME x HEMI | 1 | .02 | .52 |
| TIME x HEMI x MOOD | 1 | .02 | .38 |
| Error | 54 | .03 | |
| BAND x HEMI | 4 | .20 | 7.43*** |
| BAND x HEMI x MOOD | 4 | .00 | .11 |
| Error | 216 | .03 | |
| TIME x BAND x HEMI | 4 | .01 | .37 |
| TIME x BAND x HEMI x MOOD | 4 | .01 | .72 |
| Error | 216 | .01 | |
| SITE x HEMI | 2 | .02 | .37 |
| SITE x HEMI x MOOD | 2 | .18 | 3.02 |
| Error | 108 | .07 | |
| TIME x SITE x HEMI | 2 | .01 | .29 |
| TIME x SITE x HEMI x MOOD | 2 | .01 | .40 |
| Error | 108 | .01 | |
| BAND x SITE x HEMI | 8 | .28 | 12.71*** |

Table 65 Continued

| | | | |
|---|---|---|---|
| BAND x SITE x HEMI x MOOD | 8 | .03 | 1.22 |
| Error | 432 | .02 | |
| TIME x BAND x SITE x HEMI | 8 | .00 | .23 |
| TIME x BAND x SITE x HEMI x MOOD | | .01 | .39 |
| Error | 432 | .01 | |

Note. Time = Pre-mood induction power density versus post-mood induction power density; Hemi = Hemisphere; Band = Frequency band (Delta, Theta, Alpha, Beta 1, Beta 2); Mood = Happy versus Sad; Site = Electrode location (Frontal, Central, Parietal).

* $p < .05$, ** $p < .01$, *** $p < .001$.

These analyses failed to reveal a significant Time by Hemisphere by Mood interaction that would support the hypothesis that happy and sad mood differentially impact asymmetric cerebral activation. There was a significant Hemisphere by Mood interaction, however. This finding reveals that regardless of Time, the hemispheric activation of participants in the two mood groups differed significantly from one another. Because this effect was only significant for when all the frequency band power density values were combined, the meaning of this finding is uncertain. If this effect was limited to one or more of the individual frequency bands, one would have expected the Band by Hemisphere by Mood interaction to be significant, which was not the case.

Follow-up repeated measures analysis of variance examining each frequency band individually also failed to produce any significant Time by Hemisphere by Mood interactions that would suggest that the mood induction procedure had an appreciable influence on EEG asymmetry within any of the frequency bands.

# CHAPTER 4: DISCUSSION

## Psychometrics of EEG Asymmetry

A central methodological feature of this study involved measuring EEG asymmetry on two occasions. This design was adopted so that the temporal stability of resting EEG asymmetry could be calculated and so that group comparisons between participants with relatively stable EEG asymmetry versus those with less stable EEG asymmetry could be made.

The test-retest values reported here are comparable, but slightly lower than those reported by Papousek and Schulter (1998). In a sample of 60 (33 females, 27 males) undergraduate students, these researchers found that the average correlation (across frontal, temporal, and parietal sites) for EEG asymmetry values measured two to four weeks apart was .50, .57, 47, and .58 for Theta, Alpha, Beta 1, and Beta 2 bands, respectively. The corresponding averaged temporal stability values found in this study for the Theta, Alpha, Beta 1, and Beta 2 bands were .44, .53, .44, and .38, respectively.

Tomarken et al. (1992) is the only other report that describes EEG temporal stability for multiple frequency bands, although they only measured EEG in anterior (i.e., frontal and temporal) locations. They found averaged EEG asymmetry stability values ranging from .58 to .88 across the same five frequency bands examined in the present study. One methodological difference between their study and the present study was that they measured EEG for eight minutes instead of only two minutes. They found that the test-retest values for the longer samples was higher than when EEG was sampled for only two minutes. Importantly, the test-retest values for the first two minutes of their data were highly consistent with the results reported here.

Consistent with previous research, the results of the present study suggest that the temporal stability of EEG asymmetry is very high for a large minority of participants when EEG is measured two to three weeks apart. In addition, comparing the results of using the "standard" .3 SD criteria used by Tomarken et al. and the "relaxed" .5 SD criteria shows that the temporal stability increases only slightly when the latter operational definition of stability is used. The increase in the number of subjects in the stable group may be advantageous in terms of power. In addition, it is possible that the .3 SD criterion is too stringent. Future research comparing these two approaches will help determine the value of using a less stringent criterion for defining stable activation asymmetries. Unfortunately, the efforts made to distinguish between stable and unstable EEG groups did not lead to any support for the importance of making such distinctions in research regarding the emotional and personality correlates of asymmetric cerebral activation.

## Hierarchical Visual Processing, Mood, Personality, and EEG Asymmetry

The purpose of this component of the study was to replicate previous findings concerning the relationship between hierarchical visual processing and mood (Basso et al., 1996) and to test novel hypotheses regarding personality, hierarchical visual processing, and EEG asymmetry in posterior cortical areas.

The results failed to replicate the findings of Basso et al. (1996) regarding the correlation between hierarchical visual processing and mood. It may be that such a direct relationship between mood and visual processing does not consistently exist. However, methodological differences between Basso et al. and the present study may be partially responsible for this replication failure. Basso et al. only used male subjects and the current study involved male and female participants. It is possible that an association between mood and hierarchical visual processing is gender specific. However, post-hoc analyses using the current data set examining potential gender differences did not reveal a significant relationship between hierarchical visual processing and mood for males or females independently. Second, Basso et al.'s sample included 60 males and the current study included only 28 males. Therefore, a study with greater power may be required to replicate Basso et al.'s findings for male subjects.

In contrast, using the Rorschach location scores as the criterion variable for hierarchical visual processing, support was found for a relationship between mood and hierarchical visual processing such that higher numbers of Minor Detail location responses on the Rorschach were positively correlated with measures of negative affect and negatively correlated with measures of positive affect. This relationship was generally consistent across the subsets of inkblots, suggesting that this is a robust finding. Future research using all 10 inkblots would be useful to determine the replicability of this finding.

Despite the failure to replicate Basso et al.'s (1996) finding of a significant correlation between mood and hierarchical visual processing, the results of the present study did find support for a relationship between personality and hierarchical visual processing. The pattern of correlations suggested that global visual processing tendencies are associated with features of extraversion, behavioral activation and emotional thinking (as measured by the Globality-Differentiation Scale). These findings suggested that global visual processing tendencies are more common in people who exhibit higher levels of extraversion and higher levels of emotional thinking. When combined, these traits represent what is traditionally described as a "histrionic" style of information processing (Shapiro, 1965) and support the findings of previous research suggesting that extraverts are more prone to process information in a more "holistic" manner (Charman, 1979). However, this hypothesis deserves further empirical scrutiny. Finally, the finding that the Rorschach location variables failed to correlate with personality variables suggests that the potential relationship between personality and visual processing is not readily quantified using the Rorschach.

The final portion of the hierarchical visual processing component of this study tested whether EEG asymmetry measures correlated with global or local visual processing tendencies. The results failed to demonstrate a relationship between cortical activation and performance on the hierarchical visual processing task. As Davidson (1988) has described, it is useful to consider the difference between cortical *specialization* and cortical *activation*. That is, although a wide body of research documents that the left hemisphere is specialized for the processing of local elements of visual scenes (and vice versa; see Ivry & Robertson, 1999), this does not necessarily mean that *activation* levels of each hemisphere will correspond to specialized processing tendencies. From this perspective, differences in resting activation of each hemisphere most likely will not show a one-to-one correspondence with behavior performance on tasks thought to reflect hemispheric specialization. Another possibility is that electrical activity measured by surface EEG is not sensitive enough to activation differences that would correlate with individual differences in visual processing. For example, a recent study using fMRI did find support for the view that differences in activation of the left and right occipito-temporal cortex are associated with performance on local and global processing measures (Martinez, Moses & Frank, 1997).

Creativity, Primary Process, Personality and Asymmetric Cerebral Activation

The hypotheses in this component of the study received mixed support. First, the findings lend strong support toward the use of the Rorschach as an experimental measure of primary process cognition using the Regressive Imagery Dictionary (Martindale, 1975). Therefore, this study sets the stage for future applications of the Rorschach as a measure of primary process cognition in a variety of experimental and clinical contexts. Although only six of the 10 inkblots were used in this study, it is likely that the use of all 10 inkblots would be just as effective, or even more so, as a means of quantifying primary process cognition. A study that is currently underway in Martindale's laboratory is designed to gather a normative database of Rorschach responses using all 10 inkblots to which the RID will be applied.

A critical theoretical position in Martindale's theory of the biological basis of creativity is that more creative people show patterns of greater right hemisphere activation *only when called upon to perform a creative task* (Martindale & Hasenfus, 1978; Martindale, 1999). The results of the present study found mixed support for this hypothesis. In terms of Theta activation, higher creative participants, as defined using the Cognitive Disinhibition Scale, tended to show greater right hemisphere activation regardless of task involvement. This finding is unique to the extent that prior EEG/creativity research has focused exclusively on Alpha activation.

In terms of Alpha activation, the present study found that low creative participants tended to show greater left hemisphere activation at rest and during a creative task. High creative participants tended to show greater right hemisphere activation at rest and during a creative task. Taken together, these findings support the idea that more creative participants are more likely to show greater right hemisphere activation regardless of task involvement. These findings are limited to some extent by the fact that a significant Task by Hemisphere by Creative group interaction was found only when using the Cognitive Disinhibition Scale to define high and low creative groups rather than the composite measure of creative potential. These findings suggest that the manner in which creativity is quantified is crucial to the success of research examining the asymmetric cerebral activation patterns associated with creativity and creative task performance. Unfortunately, no association between resting or task related EEG asymmetry and Primary Process cognition was found. Future research using all 10 inkblots administered in the standardized manner used in the Comprehensive System (Exner, 1992) would be useful as a comparison to the approach used in the present study.

The findings of the present study indicated that, at least with respect to EEG asymmetry, the Cognitive Disinhibition Scale (CDS) performed better than the composite creativity measure as a means of grouping subjects that would show greater relative right hemisphere EEG asymmetry during resting baseline recordings and creative task performance. Thus, the CDS appears to be a viable means of assessing the self-report correlates of creative potential. Further support was found for the construct validity of the CDS as a measure of creative potential to the extent that it correlated positively with both the composite creativity measure and one of its subscales (the Immersion scale) also correlated significantly with primary process cognition. In sum, these findings contribute to the growing body of data supporting the use of the CDS as a measure of individual differences in creative potential (Vartanian & Martindale, 2001; Vartanian, Martindale, & Kingery, 2002).

Emotion, Cognition, Personality and EEG Asymmetry in Frontal and Parietal Regions

The results of this component of the study either failed to support the hypotheses or contradicted the hypotheses. Contrary to the Davidson's (1995) model, no support was found for an association between frontal EEG asymmetry and mood or personality. This was true regardless of EEG stability and regardless of the measures used to quantify emotion. An important methodological feature of this study was the use of multiple measures of mood and personality. This approach was adopted because prior research suggested the need to more broadly assess emotion so as to more clearly determine how frontal EEG asymmetry relates to mood and temperament (Tomarken et al., 1990). However, this approach did not result in findings that corresponded with prior research.

The failure to replicate Davidson's model is not unique to this study, however. Many previous studies have failed to find support for his model (Hagemann et al., 1999; Reid et al., 1998). Although Davidson has argued that a potent explanation for these null findings has been the failure to assess EEG on two occasions so that contrasting EEG stability groups can be compared, this methodological criticism does not apply to the present study. Thus, the current study adds to the growing body of literature that casts doubt on the generalizability and validity of Davidson's model of affective style and frontal EEG asymmetry.

Although Davidson has consistently disavowed a relationship between posterior EEG alpha asymmetry and mood, the results of this study found support for such a relationship. However, the results were opposite of those posited by Heller (1990a, 1990b), who has argued that greater relative activation of the right parietal cortex is associated with higher levels of anxiety. Although this researcher's model has evolved based on new findings and now incorporates a distinction between anxious arousal and anxious apprehension (Heller & Nitschke, 1998), the essential hypothesis is that greater activation of the right parietal lobe is associated with higher levels of anxious arousal. The findings in the current study were directly opposite to those of Heller's in that greater Alpha activation of the left posterior cortex was associated with high levels of trait anxiety and behavioral inhibition. In contrast, relatively greater levels of right hemisphere activation were associated with higher levels of optimism.

In summary, the findings concerning EEG asymmetry and mood and personality are difficult to reconcile with Davidson's (1995) and Heller's (1990a, 1990b) models. Although methodological differences may play a role, it seems unlikely that this can fully explain the contradictory findings of this study. Future research with larger samples and multiple measures of mood and personality will ultimately help determine the viability of current models of asymmetric brain activation and affective style.

The final component of this experiment was an attempt to replicate and extend the findings of Bartolic et al. (1999) regarding the effect of mood on cognition. As described above, however, the results did not support their findings. Important methodological differences between the two studies include the use of both males and females in the present study, the use of a movie to induce mood instead of the more commonly used Velten procedure (Velten, 1968), and the measurement of verbal and figural fluency for each participant. Bartolic et al. included only males because of known differences between males and females regarding performance on phonemic and spatial fluency tasks

(Ruff, 1988). However, the present study represents a stronger test of Bartolic et al.'s conclusions concerning the effects of mood on cognition by including both males and females. This idea is supported in part because there were no significant gender differences on the fluency measures and there were no significant interactions between mood and gender on any of the fluency or mood state measures.

Given that changes in verbal fluency were in the predicted direction, it is possible that predicted changes in verbal fluency may have occurred if the happy mood induction had been more potent. Future research could examine differences in the effectiveness of various mood induction procedures on verbal fluency. In addition, it is important to remember that verbal fluency was assessed by having participants write down their responses, which is not how verbally fluency is assessed clinically. It would have been helpful to have measured psychomotor speed to determine whether partialling out psychomotor speed would have influenced the pattern of results. Perhaps the most important next step in this line of research is to examine the relative effectiveness of different mood induction procedures on cognition using a variety of cognitive tasks. This research is important because there is much controversy in the neuropsychological literature regarding the effects of mood on cognition (Bartolic, et al., 1998; Davidson, 1995). Furthermore, many patients referred for neuropsychological assessment are experiencing clinically significant levels of emotional distress that may influence their cognitive performance in ways that are poorly understood at the present time.

Finally, this experiment was not successful in confirming the predictions regarding the effect of a mood induction procedure on asymmetry cerebral activation. It is certainly possible that the happy mood induction was not powerful enough to induce better than others at predicting asymmetric cerebral activation or whether the commonalities among various mood and personality constructs (i.e., behavioral activation/behavioral inhibition, positive affectivity) are the more parsimonious correlates of asymmetric cerebral activation.

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Appendix A - Informed Consent Form

**Overview of the Study**: You are invited to participate in a research project being conducted by Lisle Kingery, a doctoral-level graduate student in the Department of Psychology at the University of Maine. The purpose of this research is to see if brain waves are related to emotion, personality and thinking styles. This research is not mean to draw conclusions about participants as individuals.

**What Will You Be Asked to Do?** If you decide to participate, you will be asked to attend two experimental sessions that last two-hours each. The second session will be completed two weeks after the first one. The entire experiment is broken down into two sessions, each lasting two hours (four hours total). You will receive one credit for each hour of participation. Thus, completing both sessions will count toward FOUR credit hours.

**Session 1 description:** During Session 1, you will complete two thinking style tasks, followed by questionnaires that ask about your emotions and personality. During the second hour of Session 1, your brain waves will be recorded while you complete two more tasks that measure thinking styles. The thinking style tasks and questionnaires for Session 1 are as follows:

1. Uses test. You will be asked to think of as many uses as you can for three common objects.

2. Remote Associates Test. You will be asked to think of a word that best goes with three other target words. For example, if the three words are Cookies, Sixteen, and Heart, you would be asked what word seems to go with all of these words. (One answer is sweet).

3. Self-report questionnaires of emotion and personality. The rest of the first hour of Session 1 will be spent completing questionnaires about your emotions and personality. Each questionnaire asks you to either describe your personality or your emotions on a rating scale. Two examples are shown below. Do NOT complete the items on this form. They are just examples.

An example of an emotion questionnaire is:

Rate how often you typically experience each emotion:

0=Never 1=Rarely 2=Sometimes 3=Frequently 4=Almost always

( ) Happy ( ) Fearful ( ) Sad

An example of a personality questionnaire is:

Using the scale below, rate yourself on each item:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

___1. I'm always willing to try something new if it will be fun.
___2. I have very few fears compared to my friends.

The second hour of Session 1 involves measuring your brain waves and completing two thinking style tasks. Electroencephalograph (EEG) recordings will be made before, during, and after the two thinking style tasks. This part of the study begins with the experimenter applying electrodes to your scalp and face to allow recording of your brain waves and facial muscle movement. To attach the electrodes, it is necessary for the experimenter to mark the locations for the disks on your scalp with a red grease pencil and then lightly scrub your scalp to prepare the surface. These marks are easily removed with water. Then, the discs will be applied with a water-based gel and some surgical tape. Once the disks are attached, you will be asked to remain relaxed. It takes approximately ½ hour to attach all the electrodes and ½ hour to complete the tasks. The two thinking style tasks are:

1. Figure matching task: You will be asked to quickly choose which one of two geometric figures you think "best matches" a target geometric figure.
2. You will be shown 6 visual images and be asked to describe "what you think it might be." You will say your responses out loud and they will be audiotaped. After all six images, you will be asked a few questions to clarify your responses.

**Session 2 description.** The format of Session 2 is similar to Session 1. During the first 50 minutes, you will complete 4 questionnaires about your personality. The items are similar to the personality questionnaires completed in Session 1.

During the remaining 70 minutes, electrodes will again be applied to measure brain waves in the same manner as in Session 1. After the electrodes are applied, you will complete two tasks that involve writing as many words that start with a specific letter as you can in a one-minute time period and making as many unique, simple line drawings as you can during a one-minute period. After these tasks, you will complete two questionnaires about your emotions and then watch either a happy or a sad film clip. Then, you will be asked to repeat the tasks you completed before the film clip and repeat the same two questionnaires about your emotional reactions to the film.

**Are there any risks involved in this experiment?**

- You will be completing questionnaires about your emotions and symptoms of psychological distress (i.e., symptoms of depression and anxiety). There is some risk that you may find these questions uncomfortable. YOU DO NOT HAVE TO ANSWER ANY QUESTIONS YOU DO NOT WANT TO.

- Applying electrodes requires that the experimenter touch your scalp, neck, and face. Also, there is a chance that the application of electrodes will be discomforting because it requires rubbing a small portion of your scalp with a Q-tip that has a small amount of rubbing alcohol in it.

- Half of the research participants will be assigned to a sad film clip from a Disney movie and will be asked to engage in a sad mood as much as possible. IF FOR ANY REASON YOU ARE NOT COMFORTABLE WATCHING A SAD MOVIE CLIP, DO NOT PARTICIPATE IN THIS EXPERIMENT. If you are uncomfortable watching a sad film clip, please tell the experimenter that you do not want to participate in this experiment. You will be awarded one hour of participation credit for your time.

**What are the benefits of participation in this project?**

Benefits from participating in this study include a) obtaining extra credit toward your PSY100 final grade, b) exposure to the workings of a scientific psychological experiment, and c) the opportunity to reflect about yourself by completing a series of questionnaires about your personality, mood and thinking styles.

**Exclusion Criteria:** If you have any history of seizures or head injury (e.g., severe concussion, mild head injury), you cannot participate in this experiment. By signing the Informed Consent, you are stating that you do not have any history of such problems. You must be 18 years of age or older to participate in this experiment.

**What are my rights?:** You have the right to refuse to participate or withdraw from participation at any time, as well as the right to refuse to answer any questions asked during the research project. You will not be penalized for declining or withdrawing from participating and there will be no loss of credit for partial participation. For every one jour of participation, you will receive one credit hour.

**Confidentiality:** One piece of paper will contain your name and your research identification number. This paper will be kept in a locked cabinet in Room 353 N. Stevens, separate from all other experimental materials. Only three of the experimenters have access to this confidential cabinet. Data for this study will be collected through May 2002. At this time, the documents linking your name to the data will be destroyed. Importantly, no information, which identifies you, will be written on any experimental materials or released in any way. PLEASE DO NOT WRITE YOUR NAME OR ANY OTHER IDENTIFYING INFORMATION ON ANY OF THE EXPERIMENTAL MATERIALS.

**Contact Information:** If you have any questions about the study, you may write or phone the Principal Investigator, Lisle Kingery. (You can reach me on First Class or at 581-2071). You may contact the faculty advisors for this project, either Colin Martindale, Ph.D., or Geoffrey Thorpe, Ph.D., in the Department of Psychology. If you have any questions about your rights as a research participant, please contact Gayle Anderson, Assistant to the University of Maine's Protection of Human Subjects Review Board, at 581-1498 (or email gayle@maine.edu).

**Agreement to Participate:** Your signature below indicates that you have read and understand the above information. You will receive a copy of this form.

____________________________ __________________

Signature Date

# Appendix B - Session Outline

## Session One

Orientation to the lab and informed consent
Creative Tasks (random order)
- Alternate Uses Test
- Remote Associates Test

Self-report questionnaires (random order)
- Beck Depression Inventory-II
- Positive and Negative Affect Scale
- State-Trait Anxiety Inventory - Trait
- Creative Personality Scale
- Cognitive Disinhibition Scale
- PAD Emotion Scale
- Life Orientation Test

EEG Component of Session One
- EEG preparation
- Baseline Eyes-Closed EEG Recordings (two minutes)
- Global-Local Task
- Rorschach Task
- Completion of Location Chart for the Rorschach Task

## Session Two

Self-report Questionnaires (random order)
- Eysenck Personality Questionnaire
- Tridimensional Personality Questionnaire
- PAD Temperament Scales
- Globality-Differentiation Scale
- Behavioral Inhibition/Behavioral Activation Scale

EEG Component of Session Two
- EEG Preparation
- Baseline Eyes-Closed EEG Recordings (two minutes)
- Pre-film Mood State Measurement (two minutes)
- Pre-film Verbal and Figural Fluency Tasks (five minutes, random order)
- Film Clip (five minutes)
- Post-film Verbal and Figural Fluency tasks (three minutes, random order)
- Post-film Mood State Measurement (two minutes)
- Post-film Eyes-Closed EEG Recordings (two minutes)
- Debriefing

# Appendix C - Alternate Uses Test

*Alternate Uses Test*

INSTRUCTIONS: On each of the next three pages will appear the name of a familiar object. Write down all the different ways you can think of in which the object might be used. Do not hesitate to write down whatever ways you can think of in which the object might be used as long as they are possible uses for the object. Try to be as original and creative as you can. Write each use on a separate line.

Brick

Shoe

Newspaper

# Appendix D – Remote Associates Test

INSTRUCTIONS: In this test you are presented with three words and asked to find a fourth work which is related to all three. Write this word in the space to the right.

| | | | Correct Responses |
|---|---|---|---|
| Falling | Actor | Dust | Star |
| Broken | Clear | Eye | Glass |
| Skunk | Kings | Boiled | Cabbage |
| Widow | Bite | Monkey | Spider |
| Bass | Complex | Sleep | Deep |
| Coin | Quick | Spoon | Silver |
| Gold | Stool | Tender | Bar |
| Time | Hair | Stretch | Long |
| Cracker | Union | Rabbit | Jack |
| Bald | Screech | Emblem | Eagle |
| Blood | Music | Cheese | Blue |
| Manners | Round | Tennis | Table |
| Off | Trumpet | Atomic | Blast |
| Playing | Credit | Report | Card |
| Rabbit | Cloud | House | White |
| Room | Blood | Salts | Bath |
| Salt | Deep | Foam | Sea |
| Square | Cardboard | Open | Box |
| Water | Tobacco | Stove | Pipe |
| Ache | Hunter | Cabbage | Head |
| Chamber | Staff | Box | Music |
| High | Book | Sour | Note |
| Lick | Sprinkle | Mines | Salt |
| Pure | Blue | Fall | Water |
| Square | Telephone | Club | Book |
| Surprise | Wrap | Care | Gift |
| Ticket | Shop | Broker | Pawn |
| Barrel | Root | Belly | Beer |
| Blade | Witted | Weary | Dull |
| Cherry | Time | Smell | Blossom |

# Appendix E – Remote Associates Norms

For the Remote Associates Test, items with updated norms were obtained from http://www.socrates.berkeley.edu/~kihlstrm/remote_associates_test.html.

# Appendix F - Creative Personality Scale

INSTRUCTIONS: Please check <u>all</u> of the words that you would use to describe yourself.

Please check <u>only</u> the words that you would use to describe yourself.

| | | | | | |
|---|---|---|---|---|---|
| | Affected | _____ | | Intelligent | _____ |
| 1. | Capable | _____ | 16. | Interests-narrow | _____ |
| 2. | Cautious | _____ | 17. | Interests-wide | _____ |
| 3. | Clever | _____ | 18. | Inventive | _____ |
| 4. | Commonplace | _____ | 19. | Mannerly | _____ |
| 5. | Confident | _____ | 20. | Original | _____ |
| 6. | Conservative | _____ | 21. | Reflective | _____ |
| 7. | Conventional | _____ | 22. | Resourceful | _____ |
| 8. | Dissatisfied | _____ | 23. | Self-confident | _____ |
| 9. | Egotistical | _____ | 24. | Sexy | _____ |
| 10. | Honest | _____ | 25. | Sincere | _____ |
| 11. | Humorous | _____ | 26. | Snobbish | _____ |
| 12. | Individualistic | _____ | 27. | Submissive | _____ |
| 13. | Informal | _____ | 28. | Suspicious | _____ |
| 14. | Insightful | _____ | 29. | Unconventional | _____ |

# Appendix G - Cognitive Disinhibition Scale

Please inspect the following questionnaire carefully and ensure that you understand how the rating system works. Then, indicate your degree of agreement with each statement by writing the appropriate number in the box to the right of the statement.

-3_______-2_______-1_______0_______1_______2_______3

Strongly disagree — Neutral — Strongly agree

| | | |
|---|---|---|
| 1 | Once a thought has entered my mind, it almost always leads to others. | |
| 2 | Little events here and there trigger all sorts of ideas in me. | |
| 3 | I don't have an active imagination. | |
| 4 | I can really immerse myself in an interesting idea. | |
| 5 | I appreciate the free-floating nature of thought. | |
| 6 | My frame of mind is constantly in a problem-solving mode. | |
| 7 | I never have difficulties making decisions. | |
| 8 | My attention is completely focused when I watch a program on TV. | |
| 9 | My thoughts wander off when I'm a passenger in the bus or in a car. | |
| 10 | It is useless to apply a concept to a completely new area. | |
| 11 | Ideas that are not carefully analyzed are worthless. | |
| 12 | I perceive a categorical difference between conscious and unconscious thought. | |
| 13 | Good art has a tendency to energize the imagination. | |
| 14 | I never allow myself to cultivate any irrational thoughts. | |
| 15 | New ideas have a way of completely capturing my attention. | |
| 16 | Insights into problems only occur during moments of careful consideration. | |
| 17 | Scientific and nonscientific concepts are categorically different. | |
| 18 | I have a narrow range of interests. | |

# Appendix H - Life Orientation Test

Instructions: Please answer the following questions about yourself by writing on the answer sheet the appropriate number from 0 to 4 that best indicates the extent of your agreement or disagreement with each statement.

0 = Strongly Disagree
1 = Disagree
2 = Neutral
3 = Agree
4 = Strongly Agree

___ 1. In uncertain times, I usually expect the best

___ 2. It's easy for me to relax.

___ 3. If something can go wrong for me it will.

___ 4. I always look on the bright side of things.

___ 5. I enjoy my friends a lot.

___ 6. I hardly ever expect things to go my way.

___ 7. I'm always optimistic about my future.

___ 8. It's important for me to keep busy.

___ 9. Things never work out the way I want them to.

___ 10. I'm a believer in the idea that "every cloud has a silver lining."

___ 11. I don't get upset easily.

___ 12. I rarely count on good things happening to me.

___ 13. Overall, I expect more good things to happen to me than bad.

___ 14. Looking into the future, things can only get worse, not better.

# Appendix I – Positive and Negative Affect Scale

Please use the following scale to indicate how you USUALLY feel. Record your numeric answer to each item in the space to the left of each emotion. Give the most accurate judgment about how you feel right now.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very slightly or not at all | A little | Moderately | Quite a bit | Extremely |

| | | | |
|---|---|---|---|
| ____ | Interested | ____ | Alert |
| ____ | Energetic | ____ | Focused |
| ____ | Ashamed | ____ | Afraid |
| ____ | Depressed | ____ | Anxious |
| ____ | Attentive | ____ | Determined |
| ____ | Nervous | ____ | Active |
| ____ | Enthusiastic | ____ | Hostile |
| ____ | Motivated | ____ | Hopeless |
| ____ | Distressed | ____ | Inspired |
| ____ | Upset | ____ | Scared |

## Appendix J - Short Form of the Positive and Negative Affect Scale

Please use the following scale to indicate how you feel RIGHT NOW. Record your numeric answer to each item in the space to the left of each emotion. Give the most accurate judgement about how you feel right now.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very slightly or not at all | A little | Moderately | Quite a bit | Extremely |

| | | | |
|---|---|---|---|
| ____ | Interested | ____ | Alert |
| ____ | Ashamed | ____ | Afraid |
| ____ | Attentive | ____ | Determined |
| ____ | Nervous | ____ | Active |
| ____ | Enthusiastic | ____ | Hostile |
| ____ | Distressed | ____ | Inspired |
| ____ | Upset | ____ | Scared |

## Appendix K - Behavioral Inhibition/Behavioral Activation Scale (BIS/BAS)

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item say. Please respond to all the items, do not leave any blank. Choose only one response to each statement. Please be as accurate and hones as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options.

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

___ 1. A person's family is the most important thing in life.
___ 2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
___ 3. I go out of my way to get things I want.
___ 4. When I'm doing well at something, I love to keep at it.
___ 5. I'm always willing to try something new if I think it will be fun.
___ 6. How I dress is important to me.
___ 7. When I get something I want, I feel excited and energized.
___ 8. Criticism or scolding hurts me quite a bit.
___ 9. When I want something I usually go all-out to get it.
___ 10. I will often do things for no other reason than that they might be fun.
___ 11. It's hard for me to find the time to do things such as get a haircut.
___ 12. If I see a chance to get something I want I move on it right away.
___ 13. I feel pretty worried or upset when I think or know somebody is angry at me.
___ 14. When I see an opportunity for something I like I get excited right away.
___ 15. I often act on the spur of the moment.
___ 16. If I think something unpleasant is going to happen I usually get pretty "worked up."
___ 17. I often wonder why people act the way they do.
___ 18. When good things happen to me, it affects me strongly.
___ 19. I feel worried when I think I have done poorly at something important.
___ 20. I crave excitement and new sensations.
___ 21. When I go after something I use a "no holds barred" approach.
___ 22. I have very few fears compared to my friends.
___ 23. It would excite me to win a contest.
___ 24. I worry about making mistakes.

# Appendix L - Globality-Differentiation Scale (GDS)

Instructions: Please use the following scale to indicate the degree of your agreement or disagreement with each of the statements below. Record your numeric answer to each statement in the space provided preceding the statement. Try to describe yourself and your beliefs accurately and generally (that is, the way you are actually in most situations - not the way you would hope to be).

+4 = very strong agreement
+3 = strong agreement
+2 = moderate agreement
+1 = slight agreement
0 = neither agreement nor disagreement
-1 = slight disagreement
-2 = moderate disagreement
-3 = strong disagreement
-4 = very strong disagreement

___ 1. My strong feelings color the way I react to situations.

___ 2. I do not understand the endless political debates when the answers are so clear.

___ 3. If something bad happens to me in the morning, I can still have a good day.

___ 4. When I am with someone and they are upset, I try to see if it had anything to do with me.

___ 5. I often have drastic opinion changes about someone as I get to know them.

___ 6. I can be rational in a relationship, even when very strong feelings are involved.

___ 7. I often make decisions on a whim.

___ 8. It is hard for me to distinguish between my thoughts and feelings.

___ 9. If I overhear a conversation, I wonder if it is about me.

___ 10. When I feel strongly about something, I can put it aside easily to concentrate on something else.

___ 11. My opinions on important matters often change drastically over time.

___ 12. I basically like one special thing about each of my close friends.

___ 13. There are times when I know something but cannot put it into words.

+4 = very strong agreement
+3 = strong agreement
+2 = moderate agreement
+1 = slight agreement
0 = neither agreement nor disagreement
-1 = slight disagreement
-2 = moderate disagreement
-3 = strong disagreement
-4 = very strong disagreement

___ 14. I do not get sidetracked easily by details.

___ 15. I can describe most of my relationships with a single word.

___ 16. When things get complicated, I find it best to follow my intuition.

___ 17. I can remain objective in emotional situations.

___ 18. I get frustrated when people refuse to see the way things are.

___ 19. My feelings generally do not interfere with my mental work.

___ 20. When I first meet someone, a single quality of theirs stands our for me.

___ 21. Sometimes, I do not understand how my close friends like the things I dislike.

___ 22. I am not distracted often by lingering emotional episodes.

___ 23. Sometimes, my strong feelings prevent me from thinking logically.

___ 24. Rarely will I say things that I regret later.

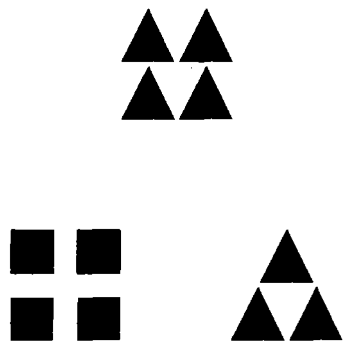
___ 25. A single gesture or expression of another can make me like or dislike them.

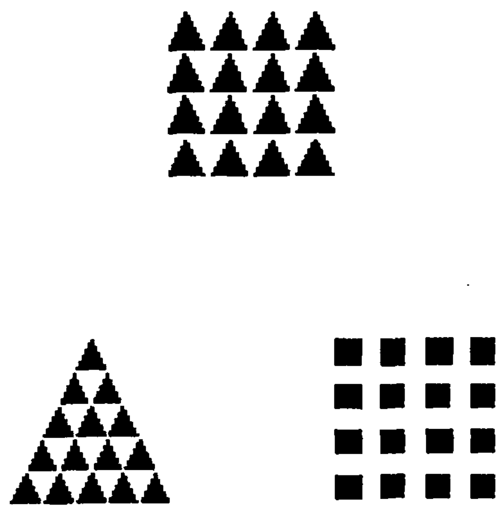
___ 26. When I feel strongly about something, I cannot get it off my mind.

___ 27. It is usually hard for me to see things clearly in an intensely emotional relationship.

___ 28. I tend to be impulsive.

Appendix M - Two Example Items from the Global-Local Task





Appendix N - Global-Local Task Answer Sheet

ANSWER SHEET

| | |
|---|---|
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |
| **X** | **X** |

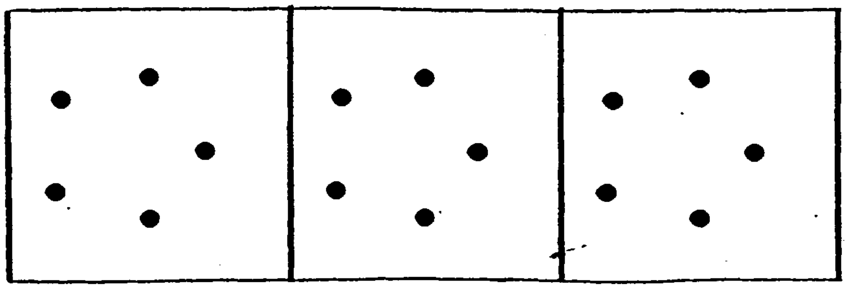
# Appendix O - Rorschach Inkblots

Appendix P - Verbal Fluency Task Response Sheet

Verbal Task

Write your responses in the spaces below. Begin in the left column and continue in the right column if necessary.

Appendix Q - Example Item from the Figural Fluency Task



## Appendix R - Descriptive Statistics for the Creativity, Mood, and Personality Variables

| Measure | Mean | Standard Deviation |
|---|---|---|
| Creativity | | |
| Alternate Uses Test | 29.60 | 11.37 |
| Remote Associates Test | 8.54 | 3.73 |
| Creative Personality Scale | 4.87 | 3.71 |
| Composite Creativity Potential | -.01 | 2.02 |
| Cognitive Disinhibition Scale | 18.10 | 11.10 |
| Primary Process | 9.79 | 2.58 |
| Secondary Process | 4.43 | 1.90 |
| Primary Process Minus Secondary Process | 5.36 | 3.84 |
| Mood | | |
| Beck Depression Inventory-II | 10.37 | 8.50 |
| State-Trait Anxiety Inventory-Trait | 42.47 | 10.03 |
| Positive Affect | 3.46 | .54 |
| Negative Affect | 2.13 | .56 |
| PAD Pleasure Emotion | 29.80 | 15.87 |
| PAD Arousal Emotion | 1.42 | 7.81 |
| PAD Dominance Emotion | 2.45 | 8.98 |
| Optimism | 7.45 | 2.62 |
| Pessimism | 5.01 | 2.92 |

Personality

| | | |
|---|---|---|
| Drive (BIS/BAS) | 10.81 | 2.29 |
| Fun (BIS/BAS) | 12.41 | 2.56 |
| Reward Responsiveness (BIS/BAS) | 17.85 | 1.40 |
| Behavioral Inhibition (BIS/BAS) | 21.33 | 4.09 |
| Extraversion | 16.47 | 3.28 |
| Neuroticism | 13.09 | 5.23 |
| Psychoticism | 9.21 | 4.48 |
| Lie Scale | 7.09 | 3.74 |
| Novelty Seeking | 18.63 | 5.04 |
| Harm Avoidance | 13.54 | 7.06 |
| Reward Dependence | 14.49 | 3.50 |
| Pleasure Temperament | 28.53 | 13.98 |
| Arousal Temperament | 20.36 | 35.36 |
| Dominance Temperament | 7.61 | 34.12 |
| Globality-Differentiation Scale | 11.00 | 19.62 |

Appendix S - Correlations Between EEG Asymmetry and Mood and Personality

Table S.1.

Correlations between Delta Band EEG Asymmetry and Mood and Personality Scales.

| Scale | Frontal | Central | Parietal |
|---|---|---|---|
| BDI-II | -.14 | .07 | -.05 |
| STAI-T | .01 | .12 | .06 |
| Positive Affect (PANAS) | -.02 | .10 | .02 |
| Negative Affect (PANAS) | -.09 | .10 | -.01 |
| Pleasure (PAD-Emotion) | .01 | .00 | .09 |
| Arousal (PAD-Emotion) | -.14 | .16 | .11 |
| Dominance (PAD-Emotion) | -.06 | -.01 | -.19 |
| Optimism-Pessimism (LOT) | .17 | .07 | -.10 |
| Extraversion (EPQ) | .05 | .07 | .14 |
| Neuroticism (EPQ) | -.09 | .12 | .02 |
| Psychoticism (EPQ) | -.12 | -.23 | -.06 |
| Behavioral Activation (BIS/BAS) | -.15 | -.13 | .03 |
| Behavioral Inhibition (BIS/BAS) | .04 | .25* | .06 |
| Pleasure (PAD-Temperament) | .00 | -.08 | -.02 |
| Arousal (PAD-Temperament) | .02 | .11 | .08 |
| Dominance (PAD-Temperament) | -.11 | -.18 | -.12 |

Note. BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait; PANAS = Positive and Negative Affect Scale; PAD-Emotion = Pleasure, Arousal, Dominance Emotion Scale; LOT = Life Orientation Test; EPQ = Eysenck Personality Questionnaire; BIS/BAS = Behavioral Inhibition/Behavioral Activation Scale; PAD-Temperament = Pleasure, Arousal, Dominance Temperament Scale.

* = $p < .05$; ** = $p < .01$.

Table S.2.

Correlations between Theta Band EEG Asymmetry and Mood and Personality Scales.

| Scale | Frontal | Central | Parietal |
|---|---|---|---|
| BDI-II | .06 | .13 | .06 |
| STAI-T | .09 | .18 | .16 |
| Positive Affect (PANAS) | -.15 | -.03 | -.23 |
| Negative Affect (PANAS) | -.08 | .09 | .15 |
| Pleasure (PAD-Emotion) | -.16 | -.19 | -.05 |
| Arousal (PAD-Emotion) | -.15 | -.05 | -.10 |
| Dominance (PAD-Emotion) | -.08 | -.02 | -.10 |
| Optimism-Pessimism (LOT) | -.09 | -.05 | -.08 |
| Extraversion (EPQ) | -.25* | -.14 | .04 |
| Neuroticism (EPQ) | -.03 | .10 | .04 |
| Psychoticism (EPQ) | -.08 | -.11 | .10 |
| Behavioral Activation (BIS/BAS) | -.22 | -.28* | .04 |
| Behavioral Inhibition (BIS/BAS) | .07 | .16 | .02 |
| Pleasure (PAD-Temperament) | -.08 | .06 | -.06 |
| Arousal (PAD-Temperament) | -.23 | -.25* | -.11 |
| Dominance (PAD-Temperament) | -.05 | .06 | -.01 |

Note. BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait; PANAS = Positive and Negative Affect Scale; PAD-Emotion = Pleasure, Arousal, Dominance Emotion Scale; LOT = Life Orientation Test; EPQ = Eysenck Personality Questionnaire; BIS/BAS = Behavioral Inhibition/Behavioral Activation Scale; PAD-Temperament = Pleasure, Arousal, Dominance Temperament Scale.

* = $p < .05$; ** = $p < .01$.

Table S.3.

Correlations between Alpha Band EEG Asymmetry and Mood and Personality Scales.

| Scale | Frontal | Central | Parietal |
|---|---|---|---|
| BDI-II | .13 | -.03 | .08 |
| STAI-T | .14 | .09 | .32** |
| Positive Affect (PANAS) | .10 | -.04 | -.24 |
| Negative Affect (PANAS) | .06 | -.08 | .23 |
| Pleasure (PAD-Emotion) | -.12 | -.10 | -.08 |
| Arousal (PAD-Emotion) | .14 | -.09 | -.15 |
| Dominance (PAD-Emotion) | .04 | -.04 | -.09 |
| Optimism-Pessimism (LOT) | -.16 | -.06 | -.30* |
| Extraversion (EPQ) | .03 | -.10 | -.07 |
| Neuroticism (EPQ) | -.01 | .06 | .20 |
| Psychoticism (EPQ) | .06 | -.10 | .07 |
| Behavioral Activation (BIS/BAS) | .04 | -.21 | .03 |
| Behavioral Inhibition (BIS/BAS) | -.08 | .11 | .28* |
| Pleasure (PAD-Temperament) | -.25* | -.19 | -.17 |
| Arousal (PAD-Temperament) | -.13 | .03 | .08 |
| Dominance (PAD-Temperament) | .03 | .03 | -.10 |

Note. BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait; PANAS = Positive and Negative Affect Scale; PAD-Emotion = Pleasure, Arousal, Dominance Emotion Scale; LOT = Life Orientation Test; EPQ = Eysenck Personality Questionnaire; BIS/BAS = Behavioral Inhibition/Behavioral Activation Scale; PAD-Temperament = Pleasure, Arousal, Dominance Temperament Scale.

* = $p < .05$; ** = $p < .01$.

Table S.4.

Correlations between Beta 1 Band EEG Asymmetry and Mood and Personality Scales.

| Scale | Frontal | Central | Parietal |
|---|---|---|---|
| BDI-II | -.08 | -.10 | -.08 |
| STAI-T | .05 | .04 | .02 |
| Positive Affect (PANAS) | -.08 | .00 | .00 |
| Negative Affect (PANAS) | -.01 | .04 | -.08 |
| Pleasure (PAD-Emotion) | -.10 | .01 | .16 |
| Arousal (PAD-Emotion) | -.30* | -.04 | -.01 |
| Dominance (PAD-Emotion) | .00 | -.03 | -.02 |
| Optimism-Pessimism (LOT) | -.06 | -.08 | .04 |
| Extraversion (EPQ) | -.13 | .10 | .12 |
| Neuroticism (EPQ) | -.09 | -.01 | -.01 |
| Psychoticism (EPQ) | .08 | -.15 | -.08 |
| Behavioral Activation (BIS/BAS) | -.04 | -.07 | .14 |
| Behavioral Inhibition (BIS/BAS) | -.10 | .11 | .02 |
| Pleasure (PAD-Temperament) | -.27* | -.06 | .03 |
| Arousal (PAD-Temperament) | -.12 | .09 | -.01 |
| Dominance (PAD-Temperament) | .04 | -.01 | -.02 |

Note. BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait; PANAS = Positive and Negative Affect Scale; PAD-Emotion = Pleasure, Arousal, Dominance Emotion Scale; LOT = Life Orientation Test; EPQ = Eysenck Personality Questionnaire; BIS/BAS = Behavioral Inhibition/Behavioral Activation Scale; PAD-Temperament = Pleasure, Arousal, Dominance Temperament Scale.

* = $p < .05$; ** = $p < .01$.

Table S.5.

Correlations between Beta 2 Band EEG Asymmetry and Mood and Personality Scales.

| Scale | Frontal | Central | Parietal |
|---|---|---|---|
| BDI-II | -.14 | -.07 | -.03 |
| STAI-T | .13 | .11 | .08 |
| Positive Affect (PANAS) | -.08 | .07 | -.02 |
| Negative Affect (PANAS) | -.06 | .22 | -.03 |
| Pleasure (PAD-Emotion) | .00 | -.04 | .15 |
| Arousal (PAD-Emotion) | -.18 | .04 | -.01 |
| Dominance (PAD-Emotion) | .13 | .04 | .07 |
| Optimism-Pessimism (LOT) | .01 | -.06 | -.03 |
| Extraversion (EPQ) | -.09 | .11 | .11 |
| Neuroticism (EPQ) | -.08 | .08 | -.02 |
| Psychoticism (EPQ) | .15 | -.12 | .08 |
| Behavioral Activation (BIS/BAS) | -.03 | .00 | .15 |
| Behavioral Inhibition (BIS/BAS) | -.07 | .08 | -.06 |
| Pleasure (PAD-Temperament) | -.03 | -.07 | -.05 |
| Arousal (PAD-Temperament) | -.16 | .10 | .02 |
| Dominance (PAD-Temperament) | .05 | -.01 | .03 |

Note. BDI-II = Beck Depression Inventory-II; STAI-T = State-Trait Anxiety Inventory-Trait; PANAS = Positive and Negative Affect Scale; PAD-Emotion = Pleasure, Arousal, Dominance Emotion Scale; LOT = Life Orientation Test; EPQ = Eysenck Personality Questionnaire; BIS/BAS = Behavioral Inhibition/Behavioral Activation Scale; PAD-Temperament = Pleasure, Arousal, Dominance Temperament Scale.

* = $p < .05$; ** = $p < .01$.

# Appendix T - Correlation Between Session One Baseline EEG Asymmetry and Creative Task EEG Asymmetry

Table T.1.

Correlations between Session One Baseline and Session One Creative Task EEG Asymmetry for the Delta Frequency Band.

| | S1 F | S1 C | S1 P | CT-F | CT-C | CT-P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .08 | | | | | |
| S1 Parietal Asymmetry | .23 | .44 | | | | |
| CT Frontal Asymmetry | .44*** | .12 | -.08 | | | |
| CT Central Asymmetry | -.08 | .65*** | .13 | .15 | | |
| CT Parietal Asymmetry | .12 | .31** | .51*** | -.07 | .20 | |

Note. S1 = Session one; CT = Creative Task; S1 F = Session one Frontal baseline asymmetry; S1 C = Session one Central baseline asymmetry; S1 P = Session one Parietal baseline asymmetry; CT-F = Session one creative task asymmetry; CT-C = Session one creative task asymmetry; CT-P = Session one creative task asymmetry.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table T.2.

Correlations between Session One Baseline and Session One Creative Task EEG Asymmetry for the Theta Frequency Band.

| | S1 F | S1 C | S1 P | CT-F | CT-C | CT-P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .21 | | | | | |
| S1 Parietal Asymmetry | .18 | .56*** | | | | |
| CT Frontal Asymmetry | .71*** | .13 | .06 | | | |
| CT Central Asymmetry | .08 | .78*** | .29* | .20 | | |
| CT Parietal Asymmetry | -.06 | .25* | .56*** | -.05 | .38** | |

Note. S1 = Session one; CT = Creative Task; S1 F = Session one Frontal baseline asymmetry; S1 C = Session one Central baseline asymmetry; S1 P = Session one Parietal baseline asymmetry; CT-F = Session one creative task asymmetry; CT-C = Session one creative task asymmetry; CT-P = Session one creative task asymmetry.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table T.3.

Correlations between Session One Baseline and Session One Creative Task EEG Asymmetry for the Alpha Frequency Band.

| | S1 F | S1 C | S1 P | CT-F | CT-C | CT-P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .47** | | | | | |
| S1 Parietal Asymmetry | .16 | .28* | | | | |
| CT Frontal Asymmetry | .54*** | .22 | .27 | | | |
| CT Central Asymmetry | .29* | .64*** | .27* | .21 | | |
| CT Parietal Asymmetry | .00 | .10 | .38** | .02 | .36** | |

Note. S1 = Session one; CT = Creative Task; S1 F = Session one Frontal baseline asymmetry; S1 C = Session one Central baseline asymmetry; S1 P = Session one Parietal baseline asymmetry; CT-F = Session one creative task asymmetry; CT-C = Session one creative task asymmetry; CT-P = Session one creative task asymmetry.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table T.4.

Correlations between Session One Baseline and Session One Creative Task EEG Asymmetry for the Beta 1 Frequency Band.

| | S1 F | S1 C | S1 P | CT-F | CT-C | CT-P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .23 | | | | | |
| S1 Parietal Asymmetry | -.05 | .28* | | | | |
| CT Frontal Asymmetry | .51*** | .29* | -.07 | | | |
| CT Central Asymmetry | .05 | .63*** | .21 | .35* | | |
| CT Parietal Asymmetry | -.01 | .23 | .69*** | -.04 | .33* | |

Note. S1 = Session one; CT = Creative Task; S1 F = Session one Frontal baseline asymmetry; S1 C = Session one Central baseline asymmetry; S1 P = Session one Parietal baseline asymmetry; CT-F = Session one creative task asymmetry; CT-C = Session one creative task asymmetry; CT-P = Session one creative task asymmetry.

* $p < .05$. ** $p < .01$, *** $p < .001$.

Table T.5.

Correlations between Session One Baseline and Session One Creative Task EEG Asymmetry for the Beta 2 Frequency Band.

| | S1 F | S1 C | S1 P | CT-F | CT-C | CT-P |
|---|---|---|---|---|---|---|
| S1 Frontal Asymmetry | | | | | | |
| S1 Central Asymmetry | .13 | | | | | |
| S1 Parietal Asymmetry | -.09 | .13 | | | | |
| CT Frontal Asymmetry | .56*** | .21 | -.16 | | | |
| CT Central Asymmetry | -.05 | .57*** | .02 | .31* | | |
| CT Parietal Asymmetry | -.02 | .15 | .61*** | .12 | .28* | |

Note. S1 = Session one; CT = Creative Task; S1 F = Session one Frontal baseline asymmetry; S1 C = Session one Central baseline asymmetry; S1 P = Session one Parietal baseline asymmetry; CT-F = Session one creative task asymmetry; CT-C = Session one creative task asymmetry; CT-P = Session one creative task asymmetry.

* $p < .05$, ** $p < .01$, *** $p < .001$.

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Lisle R. Kingery was born in Charlotte, North Carolina on June 6th, 1970. He attended Charlotte Catholic High School. He graduated with a Bachelor of Arts in Psychology from East Carolina University in December, 1992. He completed his Master's of Arts in Clinical Psychology from East Carolina University in December, 1994. He is currently a pre-doctoral intern in neuropsychology at the Ann Arbor VA Healthcare System and the University of Michigan Department of Psychiatry. He will begin a post-doctoral fellowship in clinical neuropsychology at The Johns Hopkins School of Medicine in September, 2003. Lisle is a candidate for the Doctor of Philosophy degree in Psychology from The University of Maine in August, 2003.