EEG THETA POWER DURING NECKER CUBE REVERSALS

by

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(ABSTRACT)

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The purpose of this thesis was to investigate a proposed neurophysiological model for Necker cube reversals by using electroencephalography. It is suggested that Necker cube reversals are mediated by sustained focused attention to the overall drawing with visual selective attention to vertices of the cube. The main hypotheses were that deliberate attention would increase Necker cube reversals over passive attention, there would be greater high theta power during the deliberate focusing of attention than during passive attentional processing, and there would be greater theta power in the right hemisphere.

Thirty undergraduate psychology students had monopolar EEG recorded bilaterally from frontal and parietal electrode sites. The subjects viewed computer presentations of the Necker cube under two different experimental conditions: a passive condition in which they were not instructed to influence reversals, and an active condition in which subjects deliberately shifted their focus of attention.
Repeated measures ANOVAs were performed on the integrated power of both high (5.5-7.5 Hz) and low (3.5-5.4 Hz) theta bands. For both low and high theta bands there was significantly greater theta power at right frontal (F4) than left frontal (F3) sites and left parietal (P3) than right parietal (P4) sites. Unexpectedly, there was significant enhancements of low, but not high theta power in the right frontal region during the active condition. For both frequency bands, there was greater integrated power at frontal sites then at parietal sites. More reversals were reported in the active than passive condition.
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EEG Theta Power During Necker Cube Reversals

INTRODUCTION

A recent emphasis in cognitive psychophysiology is the identification of neurophysiological substrates involved in attention. One method for accomplishing this objective is to study the electroencephalogram (EEG) of subjects while attending to specific stimuli. The Necker cube is a visual illusion that has been used to investigate visual perception for over 150 years. Because the Necker cube is an ambiguous percept, it is a useful stimulus for manipulating attentional processes that are normally unaccessible.

This introduction will examine attentional processes and discuss theories of the neurophysiology of attention. The relationship of neurophysiological substrates to EEG will be examined with emphasis on the theta band (3.5-7.5 Hz). Theories of Necker cube reversals including neural satiation and visual attention will be discussed. An attentional neurophysiological model for Necker cube reversals will be proposed. Finally, an examination of how attentional processing of the Necker cube may be correlated with EEG theta power will be addressed.
OVERVIEW OF LITERATURE REVIEW

Introduction to The Necker Cube

Figure 1 - The Necker cube.

In 1832, the Swiss naturalist Albert Necker reported an optical phenomenon which occurs upon viewing a crystal or geometrical solid (Attneave, 1971; Boring, 1942). The crystals appeared to reverse in depth spontaneously with continued viewing. Necker illustrated the illusion with a drawing of a reversing rhomboid. It later became popular to draw the illusion as a cube (Figure 1). Thus the changes in
perspective became known as "reversals" and the illusion as the Necker cube. The Necker cube has remained one of the most popular stimuli for the investigation of visual perception.

Early explanations for the Necker cube illusion were dominated by theories of neural satiation (Cohen, 1959a; Köhler & Wallach, 1944; Orbach, Ehrlich, & Heath, 1963). More recently it has been suggested that attentional processing influences the apparent reversals. This thesis examined electrophysiological evidence for attentional processes implicated in Necker cube reversals.

**Attentional Processes**

Hillyard and Picton (1979) refer to attentional processes as those central nervous system functions which enable perceptual or motor responses to be made selectively to particular stimuli in preference to others. Attention is a multidimensional construct that may be focused, selective, or divided (Wickens, 1984).

In selective attention the observer focuses upon certain stimuli and not upon others. Focused attention involves concentration upon one stimulus without interference. In a divided attention task the observer is focusing upon two or more stimuli concurrently. Crawford (1991) and Crawford and
Gruzelier (1992) call the blocking of input from unselected sources, disattention.

Attention may be focused and selective simultaneously. In any real world environment an observer is typically focused upon one or more complex stimuli made up of simpler components. It is proposed that the Necker cube is a complex stimulus composed of straight lines and angles. The observer in a Necker cube task must maintain sustained focused attention to the overall cube while disattending other stimuli. Selective attention to local features including specific lines and angles with disattention to other local features leads to the global perception of one or another pattern.

Kawabata (1986) showed that focusing upon a specific angle of the Necker cube was correlated with one or the other illusory perspective. By monitoring eye movements, Ellis & Stark (1978) showed Necker cube reversals corresponded to fixations at the externally appearing corner at the instant of a perceived reversal.

The focusing of attention may be an automatic or controlled process. An automatic process is involuntary and often nonconsciously (Kahneman & Triesman, 1984). Controlled attention involves more deliberate mental effort. Necker cube reversals may therefore occur by the deliberate or
undeliberate selection of particular angles as the foci of attention.

The term "automatic processing" has been used in the literature (e.g., Shiffrin, 1988) to define only those processes which have become nonconscious through consistent practice. Nonconscious perceptual orienting, which may also be called automatic, is often considered "preattentive" (Kahneman & Triesman, 1984) or "para-attentional" (Pribram & McGuinness, 1992). To avoid confusion, this thesis will operationally define "active attention" as the deliberate selection of particular stimuli upon which to focus attention, and "passive attention" as the nonconscious selection of attentional focus by perceptual processing.

Current emphasis in the study of attention is on the underlying neurophysiological substrates involved in these attentional processes. Two recent neural models of visual attention have been suggested by Posner and Petersen (1990) and Pribram and McGuinness (1975, 1992). Posner and Petersen's model includes a posterior system responsible for covert orienting, a ventral pathway involved in pattern recognition, and an anterior system for target detection. Pribram and McGuinness' model also includes three attentional systems: a frontolimbic formation, a tegmental pathway to the reticular nucleus of the thalamus, and a hippocampal system. The frontolimbic formation is
implicated in controlled overt orienting and familiarization (habituation). The tegmental pathway is involved in targeted conscious awareness. The hippocampal system influences familiarization through frontal corticothalamalic projections and readiness (tonic arousal) posteriorly through connections in the brainstem. The frontal cortex is involved in a supervisory attentional system (Shallice, 1988) along with other cortical and subcortical units.

These systems will be examined in greater detail in the next section. The relationship between these neurophysiological substrates and EEG will be examined in a subsequent section.

**NEUROPHYSIOLOGY OF ATTENTION**

**Neural Modularity**

A. R. Luria is often credited as the first brain scientist to approach neurophysiology from a systems perspective as opposed to the earlier localization vs equipotentiality viewpoints. Luria (1973) identified three functional units in the brain: a brainstem unit for regulating tone, waking, and mental states; a posterior cortical unit for receiving analyzing, and storing information; and a forebrain unit for the programming,
regulation, and verification of activities. According to Luria, mental activities are the result of a synthesis of functioning among the three units.

A common view is that the brain is organized into discrete modules which interact to produce mental activities (e.g., Gazzaniga, 1989). Recent attempts have been made to examine attention as a result of the neural processing in integrative brain structures (e.g. for reviews, see Posner & Petersen, 1990; Pribram & McGuinness, 1992). Attention involves several distinct neurological processes: arousal (both phasic and tonic), disengagement of current attentional focus, selection of attentional focus (active or passive), engagement of attentional focus, and preparation.

**Inferior Subcortical Mediation of Arousal**

In the performance of any mental task an optimum level of arousal should be maintained (Yerkes & Dodson, 1908). Kahneman (1973) has determined that too much arousal may decrease the amount of attentional resources that may be allocated to a stimulus. Studies of vigilance (for a review, see Parasuraman, 1984) show that level of arousal affects the ability to sustain attention.

Luria (1973) identified the brainstem as the brain unit responsible for maintaining arousal. According to Luria,
arousal consists of the regulation of muscle tone. Muscle tone is controlled via the regulation of neural activity by the reticular formation. Excitation or inhibition of neuronal firing will increase or decrease muscle tone. Pribram & McGuinness (1992) described arousal as a more phasic process by which an organism becomes excited by a novel stimulus. Pribram (1991) suggested that a system of neurons in the medial portion of the spinal cord is responsible for arousal through habituation. The neurons show a higher level of firing for a novel stimulus. The level of firing decreases with repeated presentations of the same stimulus. As this region of the spinal cord continues into the reticular formation, Pribram suggested that the arousal effects claimed for the brainstem originate in the spinal cord.

The neurotransmitters involved in this spinal cord activity are predominantly norepinephrine and serotonin (Tucker & Williamson, 1984). As norepinephrine pathways are more extensive in the right hemisphere (Tucker & Williamson, 1984), it has been suggested that the right hemisphere plays a greater role in mediating phasic arousal than does the left hemisphere (Posner & Petersen, 1990; Tucker & Williamson, 1984). Tucker & Williamson suggested that arousal is responsible for mediating attention to the external environment. Posner & Petersen (1990) suggested
that the well known neglect syndrome produced by lesions in
the right posterior brain is the result of damage to an
arousal system mediated by norepinephrine.

Posner & Petersen (1990) however, refer to arousal as
"alerting", preparation and sustainment of alertness to
process high priority signals. This tonic readiness to
respond is called "activation" by Pribram & McGuinness
(1992). According to Pribram & McGuinness, activation is
mediated by the regulatory activity of the basal ganglia
including the globus pallidus, putamen, and caudate nucleus.
The neurotransmitter activity of these nuclei is
dopaminergic which is concentrated more in the left
hemisphere and primarily in the far frontal cortex. Tucker
and Williamson (1984) suggested that the left hemisphere is
dominant for the tonic arousal associated with preparation
for responding.

Posterior Cortical Attentive Processing

The posterior cortex including the parietal and
inferotemporal cortices have been implicated in passive
attentional processes (Posner & Petersen, 1990; Fuster
1990). The parietal cortex is connected with the far
frontal cortex via the superior longitudinal fasciculus
(Williams & Warwick, 1975). The uncinate fasciculus
connects the far frontal cortex to the inferotemporal cortex (Williams & Warwick, 1975). The hippocampus lies directly medial to the inferotemporal cortex and is connected to the parietal cortex through thalamic fibers.

Studies of visual event-related potentials (ERP) generally offer support that nonconscious selection based on stimulus attributes occurs in the posterior cortex (Heinze, Luck, Mangun, & Hillyard, 1990; Kramer, Sirevaag, & Hughes, 1988; Luck, Heinze, Mangun, & Hillyard, 1990). Early appearing waveforms such as N1 and P1 are larger in amplitude at posterior electrode sites and are influenced by the physical attributes of a stimulus such as spatial location, shape, and color.

Single cell recordings have shown that location is processed at the posterior parietal cortex, shape at the posterior inferotemporal cortex and color at the central inferotemporal cortex (Fuster, 1990; Spitzer, Desimone, & Moran, 1988). Individual cells within these brain regions fire differentially according to these attributes.

The posterior parietal cortex appears to be involved in disengaging the current focus of attention so that it may be shifted to another location (e. g. Posner, Inhoff, Friedrich, & Coher, 1987; Posner, Walker, Friedrich, & Rafal, 1987). Patients with lesions of the posterior parietal cortex have difficulty shifting attention to cued
locations. They have significantly longer reaction times in tests of attentional shifting than do controls (Posner, Walker, Friedrich, & Rafal, 1987).

Mesencephalic and Diencephalic Shifting of Attention

The shifting and re-engagement of attention at a new location is directed by the superior colliculi (for a review, see Posner & Petersen, 1990). Patients with damage to the superior colliculi have deficits in shifting attention to a new location even when attention is not directed anywhere preceding the shift (Posner, 1988).

The shift of visual attention appears to be mediated by the pulvinar nucleus in the posterolateral thalamus (Posner & Petersen, 1990). Patients with unilateral thalamic lesions showed a slowing of response time in shifting of attention as compared with controls even when the subject was given plenty of time to disengage the current focus of attention (Posner, 1988). Neuronal processing by the pulvinar nucleus is mediated by the neurotransmitter GABA. By injecting the pulvinar nucleus of monkeys with a GABA inhibiting substance, shifts of visual attention were slowed (Petersen, Robinson, & Morris, 1987).
The Anterior Cingulate Gyrus and the Orienting Response

Some researchers refer to any shift of attention, deliberate or nonconscious, as orienting (Posner & Petersen, 1990; Pribram & McGuinness, 1992). The orienting reflex however, is an automatic response to a salient stimulus (Rohrbaugh, 1984). After repeated presentations of a stimulus the orienting reflex goes away or is habituated.

The orienting reflex may be eliminated by lesions of the anterior cingulate gyrus, as well as the amygdala. Positron Emission Tomography (PET) has shown increased regional cerebral blood flow in the anterior cingulate gyrus during the Stroop attentional conflict paradigm (Pardo, Pardo, Janer, & Raichle, 1990). Posner and Petersen (1990) suggest that the anterior cingulate is responsive to the operations involved in target detection.

The Limbic System

According to Pribram (1991), habituation is accomplished through the activity of the amygdala. The amygdala, located in the forebrain, is at the end of the pain and temperature pathways in the spinal cord. Lesions of the amygdala in nonhuman primates decrease the effectiveness of rewards. Patients with lesions of the
amygdala often report feelings of jamais vu (they don’t recognize a familiar place) or deja vu (they recognize an unfamiliar place).

Pribram (1991) suggested that the amygdala leads to familiarization through viscerautonomic responding to the comfort or discomfort caused by a stimulus. Visceroautonomic responding leads to memory consolidation for the stimulus. When the amygdala is damaged, the visceroautonomic responding does not occur and there is no memory consolidation upon which habituation may occur.

The amygdala responds according to the relevance of a stimulus (Pribram, 1991). Relevance is relative. A stimulus is relevant if it is significantly more or less painful or pleasurable than some standard of stimulus intensity. This standard of stimulus intensity may be derived by the context of a situation. The context of any situation is made up of irrelevant stimuli, which have either become habituated or never were salient enough to cause an orienting response.

In order to determine the context of a situation, something must keep track of the irrelevant stimuli. According to Pribram (1991), that something is the hippocampus. The CA1 cells of the hippocampal septum fire at a dominant rhythm of 6 to 8 Hz in rats, cats, rabbits, and primates (e.g. Ford, Colom, & Bland, 1989; Clin, 13
Zernicki, & Gottesmann, 1991)). Increased theta firing from the hippocampus has been observed when monkeys perform delayed alternation tasks (Crowne, Konow, Drake, & Pribram, 1972) and rats engage in exploratory activity (Vanderwolf, Kramis, Gillespie, & Bland, 1975). A fronto-hippocampal system of attention appears to determine what organisms ignore or disattend. We will return to theta at a later point in this review.

**The Far Frontal Cortex**

The far frontal cortex has been referred to as the executive processor (Pribram, 1991) or the executive system (Stuss & Benson, 1986) because it appears to moderate the overall behavior of an organism by exerting top-down influence on other brain systems. Damage to the far frontal cortex results in a decrease in the ability to perform deliberate tasks, such as overt orienting and planning.

The far frontal cortex has fiber connections to most of the rest of the brain. The superior colliculi are connected to the frontal eyefields at the superolateral far frontal cortex through the superior longitudinal fasciculus (Williams & Warwick, 1975). The frontal eyefields appear to have an inhibitory effect on the saccadic movement initiated by the superior colliculi. The shifting of attention
carried out by the superior colliculi may be mediated by the top down control of the frontal eyefields (Posner & Petersen, 1990).

The orbitofrontal cortex at the inferior far frontal cortex is reciprocally connected to the amygdala. Injury to the orbitofrontal cortex or the amygdala interferes with habituation. Thus, as the frontal eyefields appear to mediate saccadic eye movements for visual shifts in attention, the orbitofrontal cortex mediates familiarity and habituation (Pribram & McGuinness, 1992).

Finally, the dorsolateral far frontal cortex appears to be associated with both temporal and spatial ordering. Damage to the dorsolateral cortex may interfere with the sequencing of activity both temporally as in the alternating fist-palm task (Christensen, 1975) and spatially as in the Trail Making Task (Reitan, 1958). The dorsolateral cortex projects to the limbic system as well as to the medial thalamus through the superior longitudinal fasciculus (Williams & Warwick, 1975).

Pribram (1991) suggested that the dorsolateral cortex is responsible for separating relevant stimuli mediated by the amygdala from nonrelevant stimuli mediated by the hippocampus. In other words, the dorsolateral cortex separates relevance from context or figure from ground. The
distinction may be made temporally or spatially as in separating the front from the back in a Necker cube.

Cortico-Hippocampal Interaction

The hippocampus is located within the medial surface of the temporal cortex. As stated, cells of the hippocampal septum fire at the theta rhythm and show increased firing in delayed alternation no/go tasks in nonhuman primates, (Pribram, 1992). Increased theta power has been recorded from the temporal cortex of cats during visual discrimination tasks (Oatman, 1982), rats and rabbits during exploratory activity (O’Keefe & Nadel, 1978), and human epileptic patients engaging in cognitive activity with hippocampal electrode implants (Arnolds, Lopes da Silva, Aitink, Kamp, & Boeijinga, 1980).

Miller (1989) has proposed a theory to explain how the hippocampal theta rhythm may be generated during selective and focused attention. Miller drew upon Hebb’s (1949) theory of cell assemblies that proposed that information in the environment is encoded by networks of associated cells. The cells become associated by the repetitive excitations of cells adjacent to those which are directly stimulated in a primary sensory pathway. Cells which are repeatedly excited by a particular stimulus attribute form a neural
representation of that attribute based on the spatial distribution of the neurons and their dendrites.

If enough cells could become associated in this manner all of the patterns encountered in the environment could be encoded by Hebbian cell assemblies. As Miller (1989) pointed out, this is not possible. There are not enough neurons in the brain. However, there are enough neurons for cell assemblies to exist that encode local patterns in the environment such as particular stimulus attributes. Miller (1989) suggested that these local cell assemblies may become organized into global environmental cell assemblies by a temporal distribution, and thus form the basis for selective attention.

The temporal distribution consists of regular oscillations of neuronal firing between cell assemblies in the neocortex. By considering the diameter of cortical axons in different organisms, their relative transmission rates, and distances from the far frontal cortex to the hippocampus, Miller has determined that regular transmissions between the hippocampus and far frontal cortex would occur at a theta rhythm. Miller (1989) proposed that other regions of the cortex including the cingulate, parietal, and temporal cortex are directly involved to a lesser extent through polysynaptic links.
Recent studies of the amplitude frequency characteristics (AFCs) of evoked potentials (for a review see Başar-Eroğlu, Başar, Demiralp, & Schüman, 1992) have shown an increase in theta oscillations during conditions of focused attention. Subjects concentrating on the third tone in a sequence show greater theta accompanying an enhanced P3 amplitude (Demiralp & Başar, 1992). The increases were most significant at frontal sites but also occurred at parietal sites. A related finding was observed by Bruneau, Roux, Guérin, Garreau, and Lelord (1993). Theta power at fronto-central sites was highly correlated with the N1 amplitude/intensity slope, an indication of early attentional processing of a stimulus, as subjects attended auditory stimuli. Başar-Eroğlu et al. (1992) proposed a diffuse theta-response system involving cortico-hippocampal circuits may be associated with increases in theta. Additional evidence for theta production associated with attention is reviewed in the next section.

THETA

EEG Background

EEG is a measure of the electrical activity of the brain as the potential differences between pairs of
electrodes, usually placed on the scalp. A differential amplifier is used to multiply these minute voltages (microvolts) for display on a polygraph chart, oscilloscope, or computer monitor. Although the exact origin of EEG remains unproven, it is widely accepted to be the summated depolarizations of thousands of neurons in the brain.

EEG was first discovered by Richard Caton in 1875 (Andreassi, 1989). Caton placed electrodes directly on the cortical surface of the brain in rabbits and monkeys. While recording from the occipital area, he was able to demonstrate a difference in the brainwaves when a flash of light was presented in front of the animal's eyes. Hans Berger (1929) adopted Caton's new methodology and applied it to humans in 1920.

Berger noticed two distinct patterns of brainwaves in humans: a large regular wave at a frequency of 8-12 Hz, and a faster, smaller irregular wave. Berger called the large wave alpha and the smaller wave beta. Many other waves have since been identified on the basis of particular frequencies and wave morphologies. Other researchers continued to follow Berger's Greek alphabet convention and named them in order of discovery: delta, theta, kappa, lambda, and mu. The major universally recognized classifications are the four frequency bands: alpha (8-12 Hz), beta (13 Hz or greater), delta (0-4 Hz), and theta (4-8 Hz). Factor
analytic studies (for a review, see Giannitrapani, 1985) have demonstrated differential sub-bands within these four basic bands and there is some controversy about the boundaries between bands.

The earliest methodology for EEG analysis involved counting the number of waves at a particular frequency in a polygraph record. The proportion of a record during which a brain area was responding at a particular frequency could then be determined. Because alpha is the easiest wave to measure by hand, alpha was the most commonly studied EEG band until the advent of computer analysis. Opening of the eyes or engaging in any mental activity will usually attenuate alpha noticeably. This led early researchers to suggest alpha was an indicator of a resting brain.

Little additional progress was made until the 1970s when researchers began using spectral analysis. A technique for transforming a series of waveforms into algebraic coefficients had already been formulated in the 1800s by the French mathematician Fourier. Fourier was attempting to mathematically represent the distribution of heat. He found his answer in Egypt where mathematicians were representing the nodes of interference in water waves. By calculating the intersections of the sine and cosine functions for every waveform in a series of waves, Fourier was able to transform a series of waves into a polynomial expression. The inverse
transform of the polynomial expression could reproduce the original waveforms.

For relatively simple waves of regular periodicity, this was practical by hand calculations. For complex irregular waveforms such as EEG, computer technology was necessary to achieve feasible Fourier transforms. Even with computers, the complexity of EEG can lead to almost infinite calculations, so an algorithm known as the Fast Fourier Transform (FFT) was developed. In an FFT algorithm, the waveforms upon which transforms are calculated are required to conform to a Gaussian distribution.

The results of an FFT (spectral analysis) are usually represented as frequency spectra which may be summated into frequency bands. The mean area in microvolts ($\mu V^2$) of the spectra within a particular frequency band is called integrated (spectral) power. The mean amplitude ($\mu V$) of spectra within a frequency band is called mean power. Integrated power provides the most information about a particular spectrum and works well for comparisons among equal bandwidths. For comparisons of unequal bandwidths, mean power is a less biased measure. The dependent variable for the EEG measured in this study is integrated theta power.

The theta rhythm was first identified by Jung and Kornmüller in 1938 (cited in Gottesmann, 1992). The term
"theta" was first applied by Walter and Dovey in 1944 (cited in Niedermeyer & Lopes da Silva, 1982). Previously the theta band was considered part of delta. Walter and Dovey argued for an intermediate band between delta and alpha. At least two different kinds of activity have been associated with theta production. Theta waves were first associated with drowsiness and sleep. Later research indicated that theta is also involved in concentrated mental effort or attention. These findings have led some investigators (e.g., Schacter, 1977; Vogel, Broverman, & Klaiber, 1968) to speculate that there are two distinctly different types of theta which may vary in source, frequency, and wave morphology.

Animal Research

Hippocampal theta has been recorded from animals including rats, cats, rabbits, dogs, guinea pigs, gerbils, and primates (for reviews, see Crowe & Radcliffe, 1975; O’Keefe & Nadel, 1978; Vanderwolf et al., 1975). Vanderwolf et al. summarized the behavior of nonprimates into two basic types. Type 1 behaviors are operant or voluntary and include walking, running, swimming, jumping, digging, and the manipulation of objects. Type 2 behaviors are reflexive or automatic and include immobility, licking, chewing, and
urination. Only the type 1 behaviors are associated with theta production. The theta associated behaviors are more associated with active attentional processing.

Increased hippocampal theta was found in primates responding to no-go task conditions in delayed alternation tasks (Crowne et al., 1972). Pribram (1991) suggested that the hippocampal systems were processing where not to look rather than where to look. In other words, the hippocampal theta appears to be associated with a disattentional process (Crawford, 1991).

Evidence for theta involved in visual attention has been recorded from the temporal cortex, superior to the hippocampus, in cats (Oatman, 1982). Oatman found increased theta power in cats performing a visual discrimination task. The cats performed visual discrimination tasks involving concentric rings. During selective attention the cats generated greater theta power. Oatman proposed that the hippocampus functions as a gating mechanism to filter out irrelevant stimuli when engaging in selective attention.

Two distinct types of electrical activity have been identified in the hippocampus of rats, cats, rabbits, and dogs, and monkeys (for reviews see, Pribram, 1991; O'Keefe & Nadel, 1978). The dominant rhythm is a very regular oscillation of 3-7 Hz in the cat, rabbit, and dog, 6-10 Hz in the rat and gerbil, and 6-8 Hz in primates. This regular
theta rhythm is produced primarily at cell layer CA1 in the hippocampal septum (Bland & Whishaw, 1976). This type of theta occurs during REM sleep and waking exploration (Winson, 1975).

The other type of hippocampal electrical activity is irregular and generally of lower frequency, but may occur within the theta band (4-8 Hz) (Vanderwolf et al., 1975). This type of electrical activity, called large irregular activity (LIA), occurs during periods of inactivity including quiet sitting and slow-wave sleep or automatic behavior, such as eating or grooming. The generator of this irregular activity in rats appears to be the dorsal hippocampus and is mediated by the posterior hypothalamus and raphe nucleus (Gottesmann, 1992).

**Human Research**

There is growing evidence that theta is associated with attention and problem solving as well as drowsiness (for reviews, see Schacter, 1977; Okada & Urakami, 1993). Epileptic patients with intracerebral electrode implants (Brazier, 1968; Arnolds et al., 1980) have shown that the human hippocampus also produces theta that appears to increase in amplitude with cognitive activity. Controlled cognitive testing with normal subjects requires scalp
recordings. Until recently, EEG recorded from the scalp has had limited utility in determining the cerebral origin of specific frequency bands. Using the new technique of FFT dipole approximation, Michel, Lehmann, Henggeler, and Brandeis (1992), have provided evidence that theta recorded from the standard 10-20 electrode sites does have a cerebral origin at or near the hippocampus.

There is evidence for two different kinds of theta involving differential frequency bands in human research as well. Vogel, Broverman, and Klaiber (1968) administered subjects a variety of cognitive and perceptual tasks in which the most challenging was a difficult subtractions task. They calculated frequency indices based on measurements of the polygraph record. The number of seconds was counted in which theta (7 Hz or less), alpha (8-13 Hz), or beta (18-30 Hz) occurred continuously for at least one second. The standard alpha band (8-13 Hz) showed the usual inverse relationship: as task difficulty increased, alpha amplitude decreased. However, a slower alpha index (specific frequency not reported) and the theta index was correlated with efficient performance on the difficult mental subtractions task as was the theta index. They also calculated an automatization index which indicated how efficiently a subject could perform the simple repetitive tasks. The standard alpha band was inversely related, while
slow alpha and theta indices were directly related to automatization.

Vogel et al. (1968) proposed that theta indexes inhibition of two types. "Class I inhibition" is associated with the inactivation of excitatory processes and accompanies less active behavior such as relaxation and sleep. "Class II inhibition" accompanies the inactivation of particular responses allowing a particular excitatory state to become patterned or directed. This slow alpha index as well as the theta measured in their study is considered to be indicative of Class II inhibition. The authors' description of Class II inhibition is consistent with a disattentional process needed for selective attention. Class I theta is slower and more irregular than Class II theta, which is more regular and of higher frequency (for a review, see Schacter, 1977).

Many scientists have identified a locus of high theta associated with the concentration of attention (Yamaguchi, 1981) in certain tasks. This theta, often called frontal midline theta, occurs most strongly at the anterior midline and ranges in frequency from 4.5-7.5 Hz (Mizuki, 1987).

Frontal midline theta was shown to be related to the concentration of attention during the performance of a mirror drawing task (Mizuki, Takii, Tanaka, Tanaka, & Inanaga, 1982). During continuous arithmetic addition,
frontal midline theta exhibited periodicity suggesting a periodic attentional process (Mizuki, Tanaka, Isozaki, Nishijima, & Inanaga, 1980). Long theta bursts were produced at fronto-central sites during continuous performance of visual display tasks (Yamamoto, 1993; Yamamoto & Matsuoka, 1990) and is correlated with more proficient computer mouse operation. Increased frontal midline theta was recorded during a concept formation task (Lang, Lang, Kornhuber, Diekmann, & Kornhuber, 1988).

The greatest number of mental tasks involving frontal midline theta was examined by Ishihara and Yoshii (1972). They recorded EEG while subjects performed 15 different mental tasks including mathematical calculations, maze tracing, and form perception. The highest incidence of frontal midline theta occurred during a pattern recognition task. Subjects were required to identify a target diagram within an array of diagrams. The subjects may have disattended to irrelevant stimuli within the nontarget stimuli resulting in greater fronto-limbic activation.

A relationship between theta and vigilance was found by Daniel (1967). Subjects who were deficient in theta production made more errors in vigilance tasks detecting strings of numbers in tape recordings. In his review of the literature (1977), Schacter suggested increased theta reflects the occurrence of processes which enhance the
probability of detecting specific stimuli. He suggested a link between Class II inhibitory theta and processes of selective attention.

Not all subjects show frontal midline theta during the performance of mental tasks (Yamaguchi, 1981). Frontal midline theta has been correlated with individual differences in task performance. Lang et al. (1987) found that individuals who performed better at a concept formation task were characterized by larger theta mean power density. This was especially true for fronto-medial recordings. They proposed that increased theta power was associated with intentional and motivational involvement and was mediated by the frontal lobe.

Production of frontal midline theta is also associated with individual differences in personality (Mizuki, Kajimura, Nishikori, Imaizumi, & Yamada, 1984). Subjects with high scores on the extroversion scale of the Maudsley Personality Inventory and low scores on the Manifest Anxiety Scale tended to produce greater amounts of frontal midline theta than other subjects. Since extraverts have been shown to be more efficient in situations requiring divided or selective attention (Davies, Jones, & Taylor, 1984), the increased theta may be a reflection of their being more capable of disattending irrelevant stimuli.

Crawford (1990, 1991) found a differential relationship
between high and low theta bands in highly hypnotizable subjects during hypnotic pain control in a cold pressor task. High hypnotizables generated significantly greater power than low hypnotizables in the high theta (5.5-7.5 Hz) but not low theta (3.5-5.5 Hz) range in frontal, temporal, parietal, and occipital locations in both hemispheres. Crawford suggested that this increased high theta might reflect more efficient Class II inhibition (Vogel, Broverman, & Klaiber, 1968) among highly hypnotizable persons.

In addition, Crawford (1990, 1991) found lateralized shifts of theta power in high hypnotizable subjects engaging in hypnotic analgesia to the cold pressor task. High hypnotizables were significantly more left hemisphere dominant while experiencing the pain. With hypnotic analgesia they showed a dramatic increase in right theta power. Lows had no significant asymmetries in either condition. Crawford (1990, 1991, 1992) proposed that the shifts in hemispheric dominance of theta were indicative of greater cognitive flexibility in shifting from focusing on pain to imagery maintained during hypnotic analgesia.

Research has supported a relationship between enhanced theta and hypnotizability (for a review, see Schacter, 1977; Crawford, 1991). Tebēcis, Provins, Farnbach, and Petony (1975) found that high hypnotizables produced more theta
than low hypnotizables in both hypnotic and awake conditions. Sarbourin, Cutcomb, Crawford, and Pribram (1990) found that highly hypnotizable individuals generated substantially more mean theta power than did low hypnotiziable individuals in monopolar occipital, central and frontal locations. This finding was replicated by Crawford (1990, 1991). These researchers suggest superior attentional ability in highly hypnotizable subjects to be correlated with greater theta production.

Additional evidence has been found for theta power increase in the disattention to pain. Larbig et al. (1982) found that a fakir produced significantly greater integrated theta power at Pz (but not Cz) than controls when successfully eliminating the conscious perception of painful stimuli including an aversive noise of 110 dB and electric shock. The fakir's success in reducing pain may be a result of superior attentional ability used to disattend the painful stimuli. The increase in theta is consistent with an efficient far frontal/limbic attentional control system.

Frontal midline theta appears most strongly just anterior to recording site Fz at a frequency from 6-7 Hz (Inouye, Ishihara, Shinosaki, Toi, & Ukai, 1988). Recently, midline theta has also been observed during clinical EEG examinations at central and parietal recording sites (Okada & Urakami, 1993). The production of frontal midline theta
is associated with the successful performance of mental
tasks including mental arithmetic (Mizuki, Tanaka, Isozaki,
Nishijima, & Inanaga, 1980), mirror tracing (Mizuki, Takii,
Tanaka, Tanaka, & Inanaga, 1982), and pattern recognition
(Ishihara & Yoshii, 1972).

In summary, there are at least two types of theta
produced in both humans and animals: A high amplitude
regular oscillation from 6-8 Hz in primates including humans
and an irregular slower rhythm (3-5 Hz in humans) associated
with drowsiness and inactivity. While the regular, high
amplitude theta is found in the CA1 layer of the hippocampal
septum in rats (e.g., Vanderwolf et al., 1975), we have yet
to determine the precise sources of varying frequencies in
humans. Recent research (Michel et al., 1992) does suggest
that scalp recorded theta is of a hippocampal origin.

High frequency theta appears to be more associated with
attentional tasks such as problem solving, vigilance, visual
discrimination, and disattention to irrelevant stimuli or
pain. High amplitude, high frequency theta has been
recorded from fronto-central electrode deviations (for a
review, see Mizuki, 1987) as well as centro-parietal regions
(Demiralp & Başar, 1992; Larbig et al., 1982; Okada &
Uratami, 1993). Asymmetric increases in theta power have
been found in the right hemisphere during hypnotic analgesia
(Crawford 1990, 1991). Perhaps these cortical recordings of
theta are indicative of cortico-hippocampal circuits involved in the disattentional processing of irrelevant stimuli. Crawford (1990, 1991, 1992) proposed that the shifts in hemispheric dominance of theta were indicative of greater cognitive flexibility in shifting from focusing on pain to imagery maintained during hypnotic analgesia. This would require sustained attention with disattention to irrelevant stimuli.

No research has examined the production of theta during perceptual tasks such as visual illusions. It would be expected that as directed, active attention occurs, there should be an increase in theta production in comparison to less directed, nonconscious processing. Those persons more susceptible to visual illusions are thought to be better at attending the relevant stimulus (e.g., Crawford, Brown, & Moon, in press; Wallace, 1986, 1988); if this is the case, then those subjects who show more susceptibility to visual illusions may also produce more theta. The present study permitted the author to extend his interest in EEG, particularly theta, to assess the effects of attentional effort on Necker cube reversals, theta production, and hemispheric asymmetries. In the next section, we will examine how attentional processes may affect Necker cube reversals.
THE NECKER CUBE

Neural Satiation

The first major theory as to how percepts of the Necker cube are formed was proposed by the Gestalt psychologist Wolfgang Köhler (Köhler & Wallach, 1944). Köhler developed his ideas from the observations of figural aftereffects by J. J. Gibson (1933) and Köhler’s earlier supposition that objects are perceived as wholes that are not the same as the sum of their parts.

According to Köhler, any visual percept has an immediate electrotonic effect on the visual cortex. An electrotonic effect is the altered sensitivity of nervous tissue after electrical stimulation. Electrotonic effects form patterns of neural fatigue or satiation corresponding to the viewed object. Satiation patterns become equally distributed throughout the brain and allow the viewer to compensate for visual distortions. The amount of satiation to an object may indicate its stimulus intensity and distance from the viewer. Köhler’s theory became known as the "neural satiation theory".

The neural satiation theory has been used to explain Necker cube reversals in terms of alternately fatiguing cortical structures (Attneave, 1971). When a viewer first
looks upon the cube one perspective immediately prevails on
the basis of axial orientation (Orbach et al., 1963). Upon
continued viewing, the corresponding cortical structure
becomes satiated beyond a neural threshold and the other
perspective is seen. When the cortical structure
corresponding to this perspective fatigues beyond that of
the other, another reversal occurs. Because the neural
structures fatigue more rapidly with continued viewing, the
reversal rate increases over time.

The primary experimental paradigm for testing the
neural satiation theory is the use of inspection figures (I-
objects) and test figures (T-objects). The subject fixates
on the I-object for a specified interval and then views a T-
object (e.g., Cohen, 1959a; Orbach et al., 1963). The I-
object is designed to cause a pattern of satiation that will
affect perception of the T-object.

This paradigm has been used to support a neural
satiation explanation for the Necker cube illusion.
Subjects have looked at I-objects consisting of target
squares of varying orientation. These I-objects have
influenced which face is seen as the front when the Necker
cube is used as a T-object (Orbach et al., 1963). Intensity
of a Necker cube serving as an I-object may be varied by
shading (Cohen, 1959a), manipulating luminance, or drawing
the figure with incomplete lines (Babich & Standing, 1981).
According to the neural satiation theory, increasing intensity increases reversals because of greater cortical stimulation and satiation.

Although neural satiation continues to be a viable perceptual theory, it does have some shortcomings with respect to explaining all aspects of Necker cube reversals. Neural satiation theorists have ignored individual differences in reversal rate (e.g., Crawford et al., in press; Klintman, 1984; Ruggieri, Cei Bergerone, & Guerra, 1981; Wallace, 1986, 1988) and have failed to account for volitional control over reversals (Ruggieri et al., 1981).

**Attentional Processes and Reversals**

The influence of visual attention on Necker cube reversals has been apparent since the conception of the illusion. Necker himself noted that changes in visual fixation caused reversals to occur (Attneave, 1971). Although visual attention may be directed covertly without eye or head movement, visual orienting is usually associated with the overt foveation of a stimulus (Posner & Petersen, 1990).

Visual fixation during the viewing of Necker cubes was measured by Ellis and Stark (1978) with an eye movement tracker. Subjects signaled reversals with a toggle switch.
The overall scanning pattern of subjects was along a diagonal between two externally appearing corners. Reversals appeared to be correlated with longer durations of fixation at one or the other of the externally appearing corners. The authors suggested that the interpretation of a corner feature is first assigned and other elements are interpreted consistently.

Kawabata (1986) manipulated visual fixation points while subjects looked at the Necker cube. Fixation point was assigned by heavy bolding of the lines of a vertex. When attention was directed to an upper vertex, it was seen as a corner of the front face. Attention directed to a lower vertex was associated with that vertex being seen as a front corner. Kawabata concluded that depth perception of the Necker cube is determined by the vertex attended. He suggested a process which analyzes and interprets local features sequentially to lead to global perceptions.

The deliberate focusing of visual fixation is an intentional process mediated by the far frontal cortex (Pribram, 1991). Perception of Necker cube reversals also appears to be related to frontal lobe functioning. Cohen (1959b) found that unilateral frontal lobe patients reported fewer reversals of the Necker cube than normals. However, bilateral patients report more reversals than normals. Teuber (1964) suggested that unilateral lesions cause a
compensatory tendency to hold one perspective while bilateral lesions induce rapid oscillations. Perhaps damage to one dorsolateral surface disrupts figure/ground separation, whereas lesions extending through the medial forebrain prevent habituation to particular corners of the cube.

Further evidence that the Necker cube may involve frontal lobe functioning comes from electrophysiology. O’Donnell, Hendler, and Squires (1988) measured visual evoked potentials while subjects viewed either the Necker cube or an invariant cube which was physically reversed by the experimenter. The amplitude of P3 was significantly larger at Fz during illusory reversals of the Necker cube than during physical reversals. This suggests the involvement of frontal lobe cognitive processing during illusory Necker cube perception.

Intentional processes are usually associated with overt motoric behavior, but may also be produced by internal anticipatory processing. In electrophysiology, anticipatory or preparatory processing is preceded by a slow rising negative brain potential called the bereitschaftspotential (BP). Elbert, Hommel, and Lutzenberger (1985) measured the BP from subjects observing a Necker cube and signaling whether reversals occurred or did not occur twice each minute with a lever. When subjects reported that a reversal
had occurred the BP was smaller in amplitude, but earlier in onset especially over fronto-central regions. The researchers suggested a nonmotoric cognitive process which may reflect decision making interacted with the BP. This nonmotoric decision making is consistent with the proposed process of active attention, the deliberate covert selection of attentional focus.

The above findings support a hypothesis that an intentional process, involving the anterior cortex, is implicated in Necker cube reversals. We know, however, that the deliberate focusing of visual fixation is not necessary for reversals to be seen. Therefore, a nonconscious attentional process, such as passive attention may also be involved. Evidence from neuropsychology indicates that attentional spatial processing is localized in the right parietal region (Posner & Petersen, 1990). Electrophysiological support for a right posterior process involved in Necker cube reversals has also been found (Altenmüller, 1989).

Altenmüller (1989) assessed cortical DC-potential lateralization during various cognitive tasks. DC-potentials were recorded bilaterally from frontal (F3/F4, F7/F8), central (C3/C4), temporal (T3/T4, T5/T6), and temporo-parietal (PT3/PT4 midway between P3/P4 and T3/T4) electrode sites. A lateralized increase of cortical
negativity during cognitive processing was taken as an indicator of hemispheric dominance. There was a larger increase of surface negativity over the left hemisphere during language and calculation tasks, whereas music and pitch discrimination tasks resulted in an increase of surface negativity over the right hemisphere. Using this technique, Altenmüller found evidence for right hemispheric dominance especially at parietal and temporal regions during reversals of the Necker cube.

Cognitive psychologists have attempted to determine a cognitive process which might influence reversals by examining individual differences. Klintman (1984) found evidence of a relationship between creativity and Necker cube reversals. He gave undergraduates tests of original thinking in which they were required to think of alternative uses for bricks or pounds of iron. Individuals scoring high in original thinking reported more reversals of the Necker cube than did middle or low scorers. Klintman concluded that high scorers could more readily free themselves from old and well established patterns in order to form a new and different percept of the Necker cube.

Freedom from established patterns is closely related to the construct of field independence. Ruggieri et al. (1981) found a significant negative correlation between scores of field dependence and number of reversals of the Schroeder
Staircase when subjects were instructed to reverse or hold their perspective of the figure. The direction of this finding also held for the Necker cube, but failed to reach statistical significance. The authors proposed that field dependent people show greater assent to hold and reverse because of their greater suggestibility. This interpretation makes sense for the hold condition, but if suggestibility is the key factor, then an opposite relationship should have occurred in the reverse condition. Perhaps field dependents are more influenced by the field of their original perception of Necker cube orientation and show greater inertia in disrupting that field.

Individuals who are responsive to hypnosis are thought to possess greater sustained and focused attentional abilities (e.g., Crawford et al., in press). Wallace (1986, 1988) found that individuals scoring high on the Harvard Group Scale of Hypnotic Susceptibility (Shor & Orne, 1962) reported more reversals of the Necker cube than low hypnotizables. This finding was replicated by Crawford et al. (in press). Crawford et al. and Wallace (1986) proposed that individuals who are more susceptible to hypnosis are better able to sustain focused attention upon the Necker cube and disattend irrelevant stimuli.

Reisberg and O’Shaughnessy (1984) showed that disrupting subjects’ concentration by requiring them to
count backwards by sixes did slow reversal rates of eight ambiguous objects which did not include the Necker cube. Wallace (1986) replicated this finding in both high and low hypnotizables by having subjects perform mental arithmetic and subtract backwards by threes while viewing the Necker cube. Although all subjects reduced the number of reversals reported in this condition, high hypnotizables continued to report more reversals than lows in all conditions. Wallace concluded that the allocation of attention to the Necker cube was disrupted by the arithmetic task, yet high susceptibles continued to be better able to attend selectively.

In summary, attentional processes have been implicated in the perception of Necker cube reversals. It is suggested that the perception of Necker cube reversals may be initiated by either the deliberate choice of vertices within the cube as a focus of attention or by nonconscious orienting to particular corners of the cube. No research has evaluated theta production associated with directed or nondirected attention to the Necker cube. I would expect that Necker cube reversals would be correlated with the production of high theta. The deliberate selection (active attention) of particular vertices should result in greater effort to disattend irrelevant stimuli and a corresponding greater increase in high theta power than passive attending.
Individual differences in the ability to attend to the Necker cube should be associated with individual differences in high theta production. Subjects who report more reversals should produce greater high theta and especially in the right hemisphere than subjects who report less reversals.
RESEARCH OBJECTIVES

The overall goal of this study was to provide EEG evidence in support of a neurophysiological model of Necker cube reversals. Subjects were shown presentations of the Necker cube on a computer monitor while EEG was recorded bilaterally from frontal and parietal sites. Subjects fixated on a dot in the middle of each Necker cube to control visual fixation. During a condition of passive attention, subjects were asked to simply look at the fixation point on the cube and report reversals with a mouse control.

It was proposed that when a subject looks at the Necker cube one vertex of the cube becomes immediately salient and attracts the subject's attention. A global perception of the Necker cube is formed with the attended vertex as one corner of the frontmost face. As the subject continues looking at the Necker cube she/he experiences nonconscious shifts of visual attention from one vertex of the cube to another. These attentional shifts will lead to apparent reversals of figure and ground within the Necker cube.

Since these passive shifts of attention may be mediated by the parietal cortex for spatial location of the vertices and by the inferotemporal cortex for the pattern of the cube, a cortico-hippocampal circuit would allow for the
perception of figure and ground. Due to the hypothesized hippocampal involvement, it was anticipated that theta power would increase over a control baseline condition.

During a condition of active attention, the subject was asked to focus visual fixation upon the dot within the Necker cube and to alternately attend to one of two vertices. Based upon research in visual attention (Ellis & Stark, 1978; Kawabata, 1986), it was proposed that the deliberate selection of the vertex to attend would lead to reversals by the same process. However, the far frontal cortex would also be more actively involved in the top down selection and direction of attentional shifts. This would involve more actively the far fronto-hippocampal attentional system. If so, it was anticipated that more theta would be generated in the active than passive condition. It was anticipated there would be a positive relationship between the number of reversals reported and the amount of high theta power.

Based on EEG theta recordings made during conditions of sustained attention (Crawford, 1990, 1991) and DC-potential recordings from subjects observing Necker cube reversals (Altenmüller, 1989), it was anticipated that subjects would show greater right hemispheric activation during both active and passive conditions. The right hemisphere may be more involved in a sustained attentional process involving
disattention to irrelevant stimuli (Tucker & Williamson, 1984).

The proposed hypotheses were as follows:

1) Individuals reporting the greatest number of reversals will show significantly higher integrated power of high theta than subjects reporting the least amount of reversals. The number of reversals will be correlated with theta production.

2) Subjects will report more reversals in the active condition than in the passive condition.

3) Subjects will show significantly higher integrated power of high theta during the active condition than during the passive condition, and both conditions will be greater than pre- and post-control conditions.

4) Subjects will show higher integrated power of high theta over the right hemisphere than over the left hemisphere while performing all Necker cube tasks.

To establish that the high theta band is differential from low theta, analyses were also performed for low theta. As low theta may be associated with inactivity and drowsiness (Schacter, 1977), no significant differences between attentional conditions were expected for low theta power.
METHOD

Subjects

Subjects were 30 right-handed undergraduates, 9 men and 21 women, selected from a larger sample to represent a range in responses from few to many Necker cube reversals. They reported no neurological problems that would affect brain dynamics and had 20-20 or corrected vision. These subjects were drawn from a sample of 242 undergraduate psychology students who participated in a preliminary one-hour screening session.

Preliminary Screening. Volunteer subjects (N=242) from undergraduate psychology classes completed a battery of paper and pencil tests including: the Annett (1967) handedness questionnaire (Appendix B), a medical history questionnaire (Appendix C), the Beck Depression Inventory (1967), the "trait" portion of the Spielberger State-Trait Anxiety Inventory (1970), and a short form of the Eysenck Personality Inventory (1958). In addition subjects performed two timed tests of visuospatial ability: the Maze Tracing Test, and the Hidden Patterns Test (Ekstrom, French, Harman, with Dermen, 1976). Finally, a group version of the Necker cube (Appendix D) was administered.
In the group Necker cube task, the subjects looked at a drawing of a Necker cube placed on their desks. The subjects focused on a fixation point at the center of the drawing and reported reversals by placing check marks in a response booklet. The task consisted of a two-minute familiarization trial to acquaint subjects with reversals, followed by three one-minute experimental trials. The scores from the experimental trials were summated to provide a total score ($M = 47.3$, $SD = 23.6$). Total scores ranged from no reversals to 132 for the three one-minute trials.

Using this data, subjects were selected according to the criterion discussed below. This resulted in the selection of 38 right-handed undergraduate psychology students, 10 men and 28 women, participating for extra credit in their psychology classes. Eight subjects were rejected due to poor EEG recordings.

**Selection Criteria.** Subjects scoring at the extreme ranges (above 100 or below 50) of the group Necker cube task were contacted first in order to obtain the widest possible distribution of scores. The division of subjects into groups will be described just prior to the results section. Using the Annett handedness questionnaire, only right handed subjects with no familial history of left handedness were
selected. Subjects with a self-reported history of head injuries, epilepsy, or attentional deficits were precluded from further study. Only subjects with reported good vision were selected.

Upon entry to the lab a Bausch & Lomb Ortho-rater (1959) was used to verify that the subject’s static visual acuity was 20/20 or corrected. The ortho-rater is a binocular device into which slides may be inserted for tests of near and far static visual acuity, as well as contrast sensitivity. No subjects were rejected on the basis of visual acuity.

**EEG Recording System**

A Beckman Accutrace EEG machine was used to record 7 channels of analog EEG and one channel of eye movement (EOG). The data were recorded at a time constant of .03 seconds and a sensitivity setting of 7.5 uV/mm. A high frequency filter was utilized to attenuate signals greater than 50 Hz. A 60 Hz notch filter was used to reduce electrical noise.

The analog signals were converted and digitally acquired using the Computerscope ISC-16 system (R. C. Electronics, 1991) and stored on a Columbia 8086 computer hard drive. The sample period was 4 ms, yielding a sampling
rate of 250 samples per second.

Electrode sites were measured and marked on the subject's scalp with a wax pencil according to the International 10-20 System of Electrode Placement (Jasper, 1958). Beckman Silver/Silver-Chloride electrodes were applied at positions Fp, F3, F4, T3, T4, P3, and P4. The skin was mildly abraded at each site just before electrode application. The experimenter wore vinyl gloves to protect against infection. Impedance was reduced to below 5 kOhm and balanced to within 500 Ohm. Reference electrodes were applied to the earlobes and linked together for monopolar recordings. Bipolar EOG electrodes were applied superolateral to the right outer canthus and inferolateral to the left outer canthus. A ground electrode was applied to the forehead.

Procedure

The EEG recording sessions lasted about 90 minutes. This included vision testing, electrode application, EEG recording, and debriefing. The subject was seated in a 10 ft. by 10 ft. electromagnetically shielded and grounded room. The subject was given a thorough description of the procedure and all questions were answered before proceeding. After signing an informed consent, the subject's vision was
tested and electrodes were applied. All lighting was extinguished except the stimulus display computer monitor in front of the subject, the experimenter’s EEG computer monitor in back of the subject, and a stationary flashlight used to monitor the paper polygraph recordings.

The Necker cube was presented on an Apple MacPlus computer using an interactive computer program written for this specific use. The program presented written instructions, a series of fixation points, and a series of Necker cubes. Each Necker cube was 81 mm by 81 mm and presented at a distance of 100 cm for a visual angle of 4° 38’.

The subject was reclined slightly in a large chair in front of the computer monitor. Care was taken to insure that each subject assumed the same body position. The computer monitor was positioned so that the center of the screen was 100 cm from the subject’s inion. Because the height of subjects varied, downward deflection from the center of the monitor to a point level with the subject’s inion was measured. Deflections ranged from 0 to 3 cm below center for a maximum angular deflection of 1° 43’.

The computer monitor was positioned on a desk in front of the subject. The keyboard was placed on the desk drawer which was pulled out over the subject’s lap. A mouse control was placed within easy reach. The experimenter
turned off the lights, except for the monitors and flashlight, and started the computer program. To standardize reading speed and ensure cooperation, the experimenter read the presented instructions with the subject (Appendix E). The experimental design consisted of four conditions: beginning baseline, passive condition, active condition, and ending baseline.

**Beginning Baseline.** The subject was instructed to focus on a fixation point presented on the computer monitor. A dot was presented for 3 one-minute trials. Analog EEG was recorded continuously on the polygraph during all trials. Digital EEG was recorded for 32 seconds beginning 15 seconds into each trial. This made full use of the computer’s 32 second (64K) buffer while assuring that movement artifact associated with starting or ending a task were minimized.

**Passive Condition.** Immediately prior to the passive condition, the subject was allowed to view a Necker cube for one minute to become refamiliarized with the illusion. The subject was informed that in the next condition a Necker cube with a fixation point at the center was to be presented. The subject’s task was to focus on the fixation point and signal reversals with the mouse control. The subject was then instructed to hold the mouse control at the
center of her/his lap and place both thumbs over the mouse button. The subject was instructed to signal whenever the Necker cube reversed by pressing the mouse button with both thumbs simultaneously.

The computer presented 6 one-minute trials of this condition. Ninety second rest periods elapsed between trials. Analog EEG was recorded continuously during all trials. Online recording was done during the last 3 trials only. This procedure allowed the subject to become familiar with the task and establish a stable reversal rate before EEG recording. Paper polygraph recording during the first 3 trials assured the same sound level would be present during all trials. During the last 3 trials, digital EEG was recorded for 32 seconds beginning 15 seconds after the start of each trial.

Active Condition. The subject next viewed a Necker cube with a fixation point at the center and two of the corners labeled A or B (Figure 2). The subject was instructed (see Appendix E) to focus on the fixation point and not move his/her eyes from the fixation point while allowing his/her attention to alternate from one labeled corner to the other. The subject was instructed to signal reversals with the mouse control as before. The subject practiced this task for one minute before the experimental trials.
During the experimental trials, the subject’s task was to continue alternating attention between the corners, but the corners were not labeled in order to prevent introducing the confounding influence of letters. The computer presented six one-minute trials of this condition. EEG was recorded as in the passive condition.
Ending Baseline. The subject again focused upon a fixation point on the computer monitor for 3 one-minute trials. EEG was recorded as in the beginning baseline condition.

At the end of the EEG recording session, the subject was given a brief explanation of the neurological significance of their recording and provided with a segment of the paper polygraph record.

Data Analysis

Each 32 second epoch of raw EEG was edited by the experimenter using the Process Program (R. C. Electronics, 1991) and checked independently by the project supervisor, Helen J. Crawford. The EEG data from 8 of the 38 subjects contained too much muscle artifact and were not used in the analyses. For the remaining 30 subjects, the EEG data accompanying deflections in the EOG channel due to saccades or blinks were deleted. EEG segments contaminated by significant muscle artifact were rejected. After editing, the Process Program yielded two 12.28 second edited epochs of EEG for each original 32 second epoch of raw data.

Each 12.28 second edited epoch of EEG was then submitted to spectral analysis by Fast Fourier Transform (FFT) using the R. C. Electronics (1991) Computerscope
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<td>31.49 Hz</td>
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<tr>
<td>High Beta</td>
<td>31.58</td>
<td>34.42 Hz</td>
</tr>
<tr>
<td>40-Hz Band</td>
<td>38.49</td>
<td>41.67 Hz</td>
</tr>
</tbody>
</table>

To control for the distortions of unequal endpoints on the normalized frequency distribution of FFT, a Hanning window was utilized to decrease the magnitude of voltages at the beginning and ending of each epoch.
Spectral smoothing for statistical stability was not employed to avoid alteration of the data. The spectral analyses were performed by 6 undergraduate assistants and 4 other graduate students in addition to the experimenter. The resulting power spectra were summated into integrated power and mean power for 19 frequency bands (Table I). Only the first three theta bands are addressed in the present thesis; subsequent work will address the other bands.

Three of the 7 EEG channels were considered to be heavily contaminated by muscle artifact even after editing, and therefore were deleted. The temporal channels (T3 & T4) had excessive EMG from the masseters, while Fp (prefrontal or far frontal) had excessive frontalis activity. This left channels F3 and F4 for the analysis of anterior EEG and channels P3 and P4 for the analysis of posterior EEG. Channels F3 and P3 indicated EEG activity in the left hemisphere while channels F4 and P4 covered the right cerebrum.

The stimulus display program scored the number of reversals reported by each subject during each condition yielding 12 scores for each subject, 6 for the passive condition and 6 for the active condition. The scores across all conditions were combined to provide a total reversal score for each subject. On the basis of these scores, the EEG data for each subject were classified into one of three
Table II - Reversal means and standard deviations for the passive condition, active condition, and total reversals.

<table>
<thead>
<tr>
<th></th>
<th>PAS</th>
<th>SD</th>
<th>ACT</th>
<th>SD</th>
<th>REV</th>
<th>SD</th>
<th>MIN</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>67.7</td>
<td>17.4</td>
<td>80.6</td>
<td>36.2</td>
<td>148.3</td>
<td>46.8</td>
<td>76.0</td>
<td>194.0</td>
</tr>
<tr>
<td>MID</td>
<td>79.1</td>
<td>14.5</td>
<td>131.0</td>
<td>15.1</td>
<td>210.1</td>
<td>10.5</td>
<td>197.0</td>
<td>226.0</td>
</tr>
<tr>
<td>HI</td>
<td>150.0</td>
<td>90.8</td>
<td>244.4</td>
<td>82.1</td>
<td>394.4</td>
<td>160.3</td>
<td>231.0</td>
<td>703.0</td>
</tr>
</tbody>
</table>

Note. REV = total reversals; MIN = lowest total score; MAX = highest total score.

groups (Table II): high reverser (M = 394.4, SD = 160.3), middle reverser (M = 210.1, SD = 10.53), and low reverser (M = 148.3, SD = 46.85). The top ten subject reversal scores formed the high group, the middle ten subject scores formed the middle group, and the lowest ten subject reversal scores formed the low group.

Because EEG with eyeblinks was removed, it was important to confirm Wieland and Meffred's (1967) finding that blinking per se did not affect reversal rate. Wieland and Mefferd found that subjects who blinked either a lot or very little reported more reversals than subjects who blinked moderately. The authors suggested that those who blinked or inhibited blinks intentionally produced more reversals because they used blinking as a strategy to do so. However, it was their intention to increase reversals and not the blinking which was responsible for reversal rate.

The blinks evident in the EOG channel of each raw,
unedited, 32 second epoch of EEG data were tabulated by an undergraduate blind to the hypotheses or number of reversals reported. The total number of blinks and the number of blinks in each condition were correlated with the total number of reversals and the number of reversals in each condition. There were no significant relationships between blinks and reversals.

All statistical analyses were performed on an IBM mainframe computer using Statistical Analysis Software (SAS, 1989) programs. To avoid false positive results from erroneous assumptions of circularity in repeated measures ANOVAs, p-values were adjusted using the Geisser-Greenhouse (1958) epsilon.
RESULTS

Necker Reversal Scores

A repeated measures ANOVA was performed on the reversal scores. The between subjects factor was reverser group (low, middle, high). The within subjects factors included 2 levels of condition (passive vs active) and 6 levels of trial (trials 1-6). There was a main effect for group, $F(2, 27) = 17.56, p < .01$. A Tukey HSD test revealed that the

![Bar graph showing mean reversal scores by group.](image)

Figure 3 - Mean reversal scores by group.

high reverser group did report significantly more reversals
than the medium or low groups (Figure 3). However, there was no significant difference between the low and middle groups.

There was a main effect for condition, $F(1,27) = 41.71$, $p < .01$. Subjects reported significantly more reversals in the active condition ($M = 152.0; SD = 86.2$) than in the passive condition ($M = 98.9; SD = 63.9$), as is shown in

![Figure 4 - Mean reversals by condition and trial.](image)

Figure 4. Each condition consisted of 6 one-minute trials.

There was a two-way interaction between group and condition, $F(2,27) = 8.2$, $p < .01$. Additional repeated measures ANOVAs were performed separately for each reversal
group including within subjects factors of condition (passive vs active) and trial (1-6). There were significantly more reversals in the active condition than in the passive condition for both the high group, $F(1,9) = 20.87, p < .01$, and the middle group, $F = 35.10, p < .01$. However, there was no effect for condition in the low group.

![Bar Graph](image)

**Figure 5** - Mean reversals by condition and group.

**Integrated Theta Power**

Repeated measures ANOVAs were performed separately on integrated power of the low theta band (3.5-5.45 Hz) and the high theta band (5.53-7.49 Hz). The between-subjects factor
was reversal group (high reverser, middle reverser, and low reverser). The within subjects factors included: 4 conditions (beginning baseline, passive condition, active condition, and ending baseline), 3 trials (Trials 1-3), 2 regions (frontal vs parietal), and 2 hemispheres (left vs right).

**Low Theta.** There was a significant main effect for condition, $F(3,81) = 2.82, p < .05$ (Figure 6). Contrast testing revealed there was significantly greater low theta power in the active condition than in the beginning.
baseline, $F(1,27) = 7.08, p < .01$.

There was a main effect for region. There was significantly greater low theta power in the frontal region than in the parietal region, $F(1,27) = 10.16, p < .01$.

There was a two-way interaction between region and hemisphere, $F(1,27) = 37.7, p < .01$ (Figure 7). Contrast tests revealed significantly greater low theta power at F4 than at F3, $F(1,27) = 5.36, p < .03$; P3, $F(1,27) = 4.91, p < .03$; and P4, $F(1,27) = 25.48, p < .01$. There was significantly greater low theta power at F3 than at P4, $F(1,27) = 10.86, p < .01$. Finally, there was significantly

![Figure 7 - Mean integrated low theta power by site.](image-url)
greater low theta power at P3 than at P4, \( F(1,27) = 21.45, p < .01 \). To summarize, for the frontal region there was greater low theta power on the right than on the left, while the opposite relationship occurred at the parietal region. For the right hemisphere, there was greater low theta power at the frontal site than at the parietal site, but no significant anterior/posterior difference on the left.

There was a three-way interaction among condition, region, and hemisphere, \( F(3,81) = 3.4, p < .03 \). Additional ANOVAs were performed separately for each condition. For

![Figure 8 - Mean integrated low theta power by condition and site.](image-url)
each condition there was a significant two-way interaction between region and hemisphere (p < .05). A Tukey HSD test was performed on the means of each site within each condition (Figure 8).

There was significantly greater integrated low theta power at the right frontal site during the active condition than during other conditions. There was greater low theta power at the left frontal site during the two Necker cube conditions than at the left frontal site during either baseline. There was less low theta power at the left parietal site during the beginning baseline than during the other conditions. There was greater low theta power at the right parietal site during the two Necker cube than during either baseline. The frontal sites showed greater low theta power at the right frontal site than at the right parietal site during all conditions. However, only during the beginning baseline and the active condition did the left frontal site show greater theta power than the left parietal site.

No other main effects and no interactions occurred.

**High Theta.** There was a significant main effect for condition, $F(3,81) = 3.88$, $p < .01$ (Figure 9). Contrast tests revealed significantly greater high theta power in the final baseline than in the starting baseline,
Figure 9 - Mean integrated high theta power by condition. 

$F(1,27) = 7.46, p < .01$, passive condition, $F(1,27) = 11.04, p < .01$, and active condition $F(1,27) = 4.15, p < .05$. There were no other differences between conditions.

There was a significant main effect for region. There was significantly greater high theta power at the frontal region than at the parietal region, $F(1,27) = 15.08, p < .01$.

There was a significant two-way interaction between condition and region, $F(3,81) = 3.01, p < .04$. Additional repeated measures ANOVAs were calculated for the frontal region and parietal region separately (Figure 10). For the frontal region, there was no main effect for condition. In
the parietal region, there was a significant main effect for condition, $F(3, 81) = 7.39$, $p < .01$. Contrast tests revealed that for the parietal region, there was significantly greater high theta power in the final baseline than in the starting baseline, $F(1, 27) = 4.09$, $p < .05$, passive condition, $F(1, 27) = 13.57$, $p < .01$, and active condition, $F(1, 27) = 12.06$, $p < .01$.

There was a significant two-way interaction between region and hemisphere, $F(3, 81) = 28.48$, $p < .01$ (Figure 11). Contrast tests revealed significantly greater high theta power at F4 ($M = 87.1$, SD = 61.8) than at F3, ($M = 79.8$, $M = 79.8$, $M = 79.8$,
Figure 11 - Mean integrated high theta power by site.

SD = 49.6), F(1,27) = 6.66, p < .01; P3, (M = 63.74, p = 31.6, F(1,27) = 10.12, p < .01; and P4, (M = 55.5, SD = 27.2), F(1,27) = 19.08, p < .01. There was significantly greater high theta power at F3 than at P3, F(1,27) = 9.49, p < .01 and P4, F(1,27) = 21.30, p < .01. Finally, there was significantly greater high theta power at P3 than at P4, F(1,27) = 25.91, p < .01. In summary, for the frontal region, there was greater integrated high theta power at the right site than left site. For the parietal region, there was greater high theta power on the left than on the right.

No other main effects or interactions were found.
Table III - Pearson correlations among theta bands including passive and active conditions.

<table>
<thead>
<tr>
<th></th>
<th>HITH</th>
<th>PLOTH</th>
<th>PHITH</th>
<th>ALOTH</th>
<th>AHITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOTH</td>
<td>0.66</td>
<td>0.94</td>
<td>0.65</td>
<td>0.93</td>
<td>0.65</td>
</tr>
<tr>
<td>HITH</td>
<td></td>
<td>0.67</td>
<td>0.96</td>
<td>0.56</td>
<td>0.94</td>
</tr>
<tr>
<td>PLOTH</td>
<td></td>
<td></td>
<td>0.67</td>
<td>0.81</td>
<td>0.66</td>
</tr>
<tr>
<td>PHITH</td>
<td></td>
<td></td>
<td></td>
<td>0.55</td>
<td>0.93</td>
</tr>
<tr>
<td>ALOTH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.59</td>
</tr>
</tbody>
</table>

Note. For all correlations, p < .01.
LOTH = low theta; HITH = high theta,
PLOTH = low theta during the passive condition;
PHITH = high theta during the passive condition;
ALOTH = low theta during the active condition;
AHITH = high theta during the active condition.

Correlations

Pearson correlations were calculated among integrated low theta power (3.45-5.45 Hz) across conditions, integrated high theta power (5.53-7.49 Hz) across conditions, integrated low theta power during the passive condition, integrated low theta power during the active condition, integrated high theta power during the passive condition, integrated high theta power during the active condition,
Table IV - Pearson correlations among sites for total theta band.

<table>
<thead>
<tr>
<th></th>
<th>F4</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td>0.95</td>
<td>0.74</td>
<td>0.78</td>
</tr>
<tr>
<td>F4</td>
<td>0.67</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
</tbody>
</table>

Note. For all correlations, p < .01.

total number of reversals, reversals during the passive condition, and reversals during the active condition.

Each band was highly correlated with every other band (Table III). For all conditions, low theta was correlated with high theta (r = .66, p < .01).

Reversals were not correlated with any theta band for the passive condition, active condition, or across conditions. The baselines were not included separately as the Necker cube trials did not occur in baseline conditions.

In order to specifically test particular brain regions with particular conditions, additional correlations were performed among the number of reversals for the active and
Table V - Pearson correlations among sites for low theta band.

<table>
<thead>
<tr>
<th></th>
<th>F4</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td>0.92</td>
<td>0.77</td>
<td>0.73</td>
</tr>
<tr>
<td>F4</td>
<td></td>
<td>0.77</td>
<td>0.80</td>
</tr>
<tr>
<td>P3</td>
<td></td>
<td></td>
<td>0.91</td>
</tr>
</tbody>
</table>

Note. For all correlations, p < .01.

Passive conditions separately and integrated theta power for each of the three bands (total, low, high) at each electrode site (F3, F4, P3, P4). Integrated theta power at each site was highly correlated to theta power at every other site (Tables IV, V, & VI). Reversals in either condition were uncorrelated with any theta band at any site.
<table>
<thead>
<tr>
<th></th>
<th>F4</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td>0.97</td>
<td>0.72</td>
<td>0.75</td>
</tr>
<tr>
<td>F4</td>
<td>0.63</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td></td>
<td></td>
<td>0.94</td>
</tr>
</tbody>
</table>

Note. For all correlations, $p < .01$. 

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DISCUSSION

REVERSALS

As hypothesized, subjects reported significantly more reversals in the active condition than in the passive condition. This is consistent with the findings by Ruggieri et al. (1981) that Necker cube reversal rate can be influenced volitionally. The active focused attention instructions increased the number of reversals reported.

The subjects in this study were using the technique of volitionally shifting the focus of visual attention from one vertex of the Necker cube to another. The fact that reversal rate was increased by this technique is evidence that higher-order attention is a contributive factor to Necker cube reversals production.

One might argue that this result constituted an order effect as the passive condition always preceded the active condition. However, if that were the case, then the mean reversals for each trial within a condition should have increased progressively from the first through the sixth trial of that condition. This was not the case as there was no significant effect for trial.

An interesting individual difference emerged in the form of a group by condition interaction. For both the high
reverser and middle reverser groups, more reversals were reported in the active condition than in the passive condition. In the low reverser group alone, there was no effect for condition. The strategy of deliberately shifting the focus of attention was not effective for this group.

This finding provides additional support for the influence of attentional ability on Necker cube reversals and is consistent with prior research findings. When the attention of subjects is distracted, by mental arithmetic or other visual tasks (Reisberg & O’Shaughnessy, 1984; Wallace, 1986, 1988), the number of Necker cube reversals reported is reduced. High hypnotizables have reported more reversals of the Necker cube than low hypnotizables (Crawford et al., in press; Wallace, 1986, 1988). Crawford (1989; Crawford & Allen, 1983) and Wallace (1986, 1988) proposed that high hypnotizables possess greater cognitive flexibility and are better at sustaining focused attention to the Necker cube while disattending irrelevant stimuli. Just as low hypnotizables have difficulty sustaining attention in tasks, low reversers may have difficulty deliberately sustaining and switching the focus of visual attention in the Necker cube task.
INTEGRATED Theta POWER

**Major Findings.** Support for the hypothesis that low theta band would not differ between conditions as did high theta band was not established. Overall low theta band correlated significantly ($r = .66, p < .01$) with high theta band, accounting for 43% of the variance. For both low theta and high theta, there were main effects for condition and region. There was significantly greater integrated theta power in the frontal region than in the parietal region for both high and low theta. For both high and low theta bands, one of the baseline conditions differed from one or more of the other conditions. However, my hypothesis that there would be greater integrated high theta power during the active condition than during the passive condition was not supported. Rather, significant differences were observed in low theta (Figure 8).

There was a significant interaction between region and hemisphere for both theta bands. There was greater integrated theta power at the right frontal site than at the left frontal site. This was consistent with my hypothesis that there would be greater integrated high theta power in the right hemisphere during both conditions of the Necker cube task. However, an opposite asymmetry occurred in the parietal region. Posteriorly, there was greater integrated
theta power on the left than on the right.

A condition by region interaction occurred for high theta but not for low theta. There was greater integrated high theta power during the final baseline than during other conditions in the parietal region. A condition by region by hemisphere interaction occurred in the low theta band but not for high theta. We will discuss each of these effects in more detail for each band separately.

My hypothesis that the high reverser group would show greater integrated theta power than the middle or low group was not supported. There was no correlation between reversals and integrated high theta power as predicted.

**Integrated High Theta Power.** There was significantly greater high theta power at the frontal region than at the parietal region. It is well known that theta tends to show a greater distribution in the anterior part of the brain than in the posterior. The greater frontal distribution of theta was first noted by Rémond and Lesèvre (1957; cited in Başar-Eroğlu et al., 1992).

The most localized recording of theta is that of frontal-midline (Fm) theta (e.g., Mizuki et al., 1984). The largest amounts of Fm theta have been recorded at a position just anterior to electrode site Fz at the frontal midline. The production of frontal midline theta is associated with
the successful performance of mental tasks including mental arithmetic (Mizuki et al., 1980), mirror tracing (Mizuki et al., 1982), and pattern recognition (Ishihara and Yoshii, 1972). The greater amount of theta produced anteriorly in the present study suggests a similar process occurred during the conditions of my experiment.

There was greater integrated high theta power in the right than left hemisphere in the frontal region, yet the opposite dominance pattern was observed in the parietal region. An opposite asymmetry was demonstrated at the parietal region. There was significantly greater integrated high theta power at the left parietal site than at the right parietal site. This was not consistent with the hypothesis that there would be greater integrated high theta power in the right hemisphere during all conditions. My hypothesis had been there would be greater integrated power of high theta in the right hemisphere than in the left hemisphere, but this was only substantiated in the frontal region. Greater DC-potentials for the right hemisphere during Necker cube reversals were found by Altenmüller (1989).

The importance of considering anterior and posterior brain dynamics in cerebral asymmetries has recently been emphasized (e.g., Crawford, 1989; Gruzelier, 1990). Crawford and her associates (Crawford, 1989; Crawford, Mészáros, & Szabó, 1989) reported differential
anterior/posterior alpha and beta power changes in high and low hypnotizables during hypnotic induction and hypnotic responding. With neuropsychological testing, Gruzelier (Gruzelier & Warren, 1993) has shown that high hypnotizables are superior to lows at left anterior tasks, such as word fluency during waking conditions. As subjects become hypnotized, highs develop performance decrements in the left anterior tasks while the performance of lows is enhanced. Gruzelier (1990) interprets this result as a shifting of attentional resources from left anterior focal attention during hypnotic induction to right posterior visualization during hypnotic responding. Both processes are necessary for hypnosis, yet they occur in opposite hemispheres. Perhaps a similar anterior/posterior asymmetrical process occurs in the Necker cube task.

An hemispheric asymmetry was found in mediating intention but not selective attention by Verfaellie, Bowers, and Heilman (1988). Intentional responding with a specified hand showed right hemispheric dominance while the location of a visual stimulus demonstrated no asymmetry. They proposed that intention is mediated by a frontal system and attention involves a temporo-parietal system. Perhaps the intentional component of selecting a focus in the Necker cube task influenced the right frontal asymmetry but a different process was operative at posterior sites. Future
research using neuroimaging techniques such as positron emission tomography (PET) is necessary to clarify which structures show increased cerebral metabolism during Necker cube reversals.

For high theta there was significantly greater integrated theta power in the parietal cortex during the final baseline than during the other conditions. My hypothesis that there would be greater theta power in the active condition than during the passive condition was not supported. Rather, the differences were found in low theta (discussed in the next section).

Support for the hypothesis that high reversers would produce greater high theta power than middle reversers or low reversers was not established. A potential problem with my analysis was the assignment to groups. Subjects were assigned to reverser groups post hoc on the basis of reversal scores in the EEG lab. This may not have provided sufficient variance in scores.

A concordant finding was the lack of a significant relationship between reversals and integrated high theta power as predicted. I had proposed that greater sustained attention and disattention leading to more reversals would result in greater high theta production. The continuous EEG recordings used in this study may have failed to account for the temporal distribution of theta production associated
with Necker cube reversals. Perhaps theta is only produced to a greater extent just prior to and during reversals. A more temporally precise measure of theta within a short period prior to a reversal report could address this problem.

**Integrated Low Theta Power.** As with high theta, there was significantly greater integrated low theta power at the frontal region than at the parietal region. This finding is consistent with the observations of Rémond and Lesèvre (1957; cited in Başar-Eroğlu et al., 1992) that theta has a greater anterior distribution. It suggests that the sources of low theta and high theta are locally similar, although there were some differences in the power distribution in the two conditions.

The same region by hemisphere interaction which occurred for high theta was also evident for low theta. There was greater integrated low theta power at the right frontal site than at the left frontal site, and greater low theta power at the left parietal site than at the right parietal site. This was not consistent with my hypothesis that low theta would not vary as did high theta. This unexpected finding suggests that the production of low theta may have been associated with a similar process that resulted in the generation of high theta.
There was greater integrated power of low theta at all sites during the active condition than during the beginning baseline. If low theta production was indeed associated with the attentional process proposed for high theta, this finding is in the direction of my hypothesis that there would be greater high theta power in the active condition than during the passive condition. The degree of cognitive effort between the active condition and a baseline was sufficient to produce a significant difference in theta production. Because the baseline conditions involved sustained attention as well as the experimental conditions, and the difference did not occur for the final baseline, it is difficult to draw any solid conclusions from this evidence.

A three-way interaction among condition, region, and hemisphere occurred for low integrated theta power. There was significantly greater integrated low theta power at the right frontal site during the active condition than at the right frontal site during other conditions. This finding is consistent with the production of low theta associated with an active attentional process involving the right frontal region (Verfaille et al., 1988).

Thus, the low theta findings provide support for an anterior distribution of theta, a right anterior and left posterior attentional process, and the association of theta
with an active attentional process. Implications of the similar findings for low and high theta for my neurophysiological model of Necker cube reversals are addressed in the next section.

Necker cube reversals were shown to interact with the bereitschaftspotential (BP), a slow rising negative brain potential preceding intentional behavior (Elbert et al., 1985). O'Donnell et al. (1988) measured visual evoked potentials while subjects viewed either Necker cubes or an invariant cube which were physically reversed by the experimenter. The amplitude of P3 was significantly larger at Fz during illusory reversals of the Necker cube than during physical reversals. Theta production has been correlated with N1 amplitude/intensity slopes during auditory attentional tasks (Bruneau et al., 1993). The amplitude frequency characteristics of P3 waves during visual and auditory attentional tasks have shown increases in theta during enhanced attention (Demiralp & Başar, 1992). Perhaps future research of event-related potentials to Necker cube reversals could discriminate associated theta production.

A possible flaw with this study was the choice of baseline conditions. During both the beginning and ending baseline conditions, the subjects visually fixated a dot on the computer monitor. This condition was chosen as it was
anticipated that focusing on a simple stimulus such as a point would result in relatively little attentional processing compared to attending a complex stimulus such as the Necker cube. In retrospect, this would appear to be an error. The visual fixation of any stimulus requires focused attention including disattention to irrelevant stimuli. Thus, any differences in theta generation between the experimental and baseline conditions due to my attentional manipulation may have been confounded. One possible explanation for the greater power in the final baseline is that familiarity with the task by the last trial led to greater skill in sustaining attention to the fixation point while disattending other stimuli.

Implications for the Neurophysiological Model

A neurophysiological model of Necker cube reversals was proposed that included the frontal cortex, the posterior cortex, and cortico-hippocampal circuits. According to my model, Necker cube reversals occur by the deliberate (active attention) or nonconscious (passive attention) selection of vertices within the drawing as the foci of attention while disattending irrelevant stimuli. The local perception of vertices within the drawing leads to a global perception of cube orientation and reversals (Kawabata, 1986).
The hypothesis that Necker cube reversals would be influenced by the manipulation of visual attention was supported by the finding of increased reversals in the active condition. The instructions to select the focus of attention increased the number of reversals reported in both the high and middle reversal groups. The lack of an effect for the low group may reflect an important individual difference in attentional ability (Crawford et al., in press; Wallace, 1986, 1988). Worthy of further investigation is whether the low reversers exhibit greater difficulty in directing attention, such as sustaining attention to the Necker cube and selectively attending particular vertices.

In my model, passive attention is suggested to be mediated by the posterior cortex including the inferotemporal cortex for pattern and the parietal cortex for spatial characteristics. Active attention is mediated by the frontal cortex. Based on previous electrophysiological findings (Altemüller, 1989). I had predicted that the right hemisphere would be dominant for both types of attention. This was substantiated in the frontal, but not parietal region.

According to my model, cortico-hippocampal circuits oscillating at a theta rhythm between the far frontal cortex and the hippocampus, as well as the parietal cortex and
hippocampus encode global representations of the environment (Miller 1989, 1991). The use of these cortico-hippocampal circuits to disattend irrelevant stimuli may result in greater production of regular, high amplitude theta (high theta) possibly by cell layer CA1 of the hippocampal septum (O'Keefe & Nadel, 1978).

For both high and low theta, there was greater integrated power at the frontal region than at the parietal region. If theta recorded at the scalp has hippocampal origin as recently found by Michel et al. (1992), the right hippocampus may be more greatly involved in the fronto-hippocampal circuit during sustained attention to a visual object. The hippocampus has strong connections to the far frontal cortex via the superior longitudinal fasciculus and the median forebrain bundle. As the median forebrain bundle passes directly inferior to the frontal midline cortex, electrical potential changes within the median forebrain bundle may be recorded from the overlying cortical surface. The parieto-hippocampal circuit may either be different or have fewer connecting fibers, either of which could lead to less theta being recorded at the surface.

The Fm theta rhythm occurs at around 6-8 Hz (Yamaguchi, 1981). I had hypothesized that this high theta band would be more affected by active attention, but this was not the case. Fm theta at 6-8 Hz may occur with effortful higher
cognitive problem solving tasks. I also found a significant difference in anterior-posterior distribution for the low theta band. The largest study of human hippocampal EEG (Brazier, 1968) found a peak of 2-4 Hz in the hippocampus of 30 patients, but greatest coherence with the cortex occurred from 4-8 Hz. Although Fm theta may be related to hippocampal theta, it may not account for the total frequency distribution produced by the hippocampus in attentional processing.

If a cortico-hippocampal circuit is also operative in the posterior brain, it could be expected that large amounts of theta could be recorded from the parietal cortex. Increased theta power during conditions of attention have been recorded from central and parietal sites in previous research (Demiralp & Başar, 1992; Larbig et al., 1982; Okada & Urakami, 1993). The lack of a direct connection between the hippocampus and the parietal cortex may have reduced the amount of theta recordable from parietal sites in my study.

The greater theta power for both bands in the right frontal region was consistent with a right hemispheric attentional process influencing Necker cube reversals. The opposite asymmetry found for the parietal cortex is an unexpected result. Undergraduate research in our department utilizing topographical brain mapping has provided further evidence of this theta anterior/posterior asymmetry for the
Necker cube task (Crawford, personal communication, June, 1993). Future research utilizing topographical brain mapping of more sites with the Necker cube, as well as other perceptual and attentional tasks may, help to understand this phenomenon.

SUMMARY

As hypothesized, subjects reported significantly more reversals in the active condition than in the passive condition. The active focused attention instructions increased the number of reversals reported. The fact that reversal rate was increased by this technique is evidence that higher-order attention is a contributive factor to Necker cube reversals production. The strategy of deliberately shifting the focus of attention was not effective for the low group.

Support for the hypothesis that low theta band would not differ between conditions as would high theta band was not established. Low theta was highly correlated with high theta. There was significantly greater integrated theta power in the frontal region than in the parietal region for both high and low theta. There was a significant interaction between region and hemisphere for both theta bands. There was greater integrated theta power at the
right frontal site than at the left frontal site. This was consistent with my hypothesis that there would be greater integrated high theta power in the right hemisphere during both conditions of the Necker cube task. However, an opposite asymmetry occurred in the parietal region.

Consistent with theta associated with an active attentional process, there was significantly greater integrated low theta power at the right frontal site during the active condition than at the right frontal site during other conditions. There was greater integrated low theta power during the active condition than during the beginning baseline.

My hypothesis that the high reverser group would show greater integrated theta power than the middle or low group was not supported. Contrary to predictions, there were no correlations between reversals and high theta integrated power.
REFERENCES


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*Electroencephalography and Clinical Neurophysiology, 6,* 235-255. (as cited in Başar-Eroğlu et al., 1992)


Walter, W. G., & Dovey, V. J. (1944). Electroencephalography in cases of sub-cortical tumor. *Journal of Neurology and Neurosurgical Psychiatry, 7*, 57-65 (as cited in Niedermeyer & Lopes da Silva, 1982)


APPENDIX A - INFORMED CONSENT FORM

Knebel/Crawford EEG Study, Exp # 018, Fall 1992

The purpose of this experiment is to examine electroencephalographic evidence for cognitive and perceptual mechanisms involved in the Necker cube illusion. You will be looking at the Necker cube illusion displayed on a computer monitor while your brainwaves are recorded. In order to record your brainwaves, a total of ten electrodes will be applied to your head: six on the scalp, two on the forehead, two on the earlobes, and two beside your eyes. The electrodes will be held in place by a thick electrolyte cream. All cream will be removed by the experimenter with a damp cloth at the end of the experiment.

The electrode sites will be marked with a wax pencil prior to application. All marks will be removed after the experiment. Pressure from the wax pencil may be slightly uncomfortable during the marking. The electrode sites will be cleaned with a cue tip and skin cleaner to remove skin oils before the electrodes are applied. Abrasion from cleaning may cause minor discomfort. To insure your safety from infection, the experimenter will wear clean rubber gloves and use thoroughly sanitized electrodes.

This experiment will take two hours and you will be given two hours of credit in your psychology class. All data will be kept in confidential files.

Consent

The information accumulated by this research may be used for research and educational purposes and information relating to my responses may be presented at scientific meetings and/or published and republished in professional journals or books, or used for any other purpose which Virginia Tech’s Department of Psychology considers proper in the interest of education, knowledge, or research. Provided, however, that it is specifically understood that in any such use or publication I shall not be identified by name.
I understand that this research project has been approved by the Human Subjects Committee, Department of Psychology, and the Virginia Tech Institutional Review Board, and if I should have any questions I should contact the following:

Tim Knebel 231-8146 Graduate student
Heilen Crawford, Ph.D. 231-6520 Researcher
Joseph Franchina, Ph.D. 231-5664 Chair, Human Subjects Committee
Ernest Stout, Ph.D. 231-5281 Chair, Institutional Review Board

I have had the study described to me and all questions answered. I hereby agree to voluntarily participate in the research project under the conditions described above. I am participating freely, in full understanding that I need not participate if I do not wish to, and if I participate, I may withdraw at any time without penalty. My vision is 20/20 or corrected so that I can easily see information from both eyes that is presented in front of me on a computer monitor.

Signature: _______________________
Date: _______________________

Soc. Sec: _______________________
Psych Class: ___________________
APPENDIX 8 - ANNETT HANDEDNESS QUESTIONNAIRE

NAME __________________________ ID # __________________________ DATE __________________________

PLEASE INDICATE WHICH HAND YOU HABITUALLY USE FOR EACH OF THE FOLLOWING ACTIVITIES BY CHECKING THE APPROPRIATE COLUMN:

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>ALWAYS LEFT</th>
<th>USUALLY LEFT</th>
<th>LEFT OR RIGHT</th>
<th>USUALLY RIGHT</th>
<th>ALWAYS RIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To write a letter legibly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. To throw a ball to hit a target?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3. To hold a racket in tennis, squash or badminton?</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. To hold a match whilst striking it?</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. To cut with scissors?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. To guide a thread through the eye of a needle?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. At the top of a broom while sweeping?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. At the top of a shovel when moving sand?</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. To deal playing cards?</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>10. To hammer a nail into wood?</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. To hold a toothbrush while cleansing your teeth?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. To unscrew the lid of a jar?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Handedness of mother: left ____ right ____ ambidextrous (explain) ____

Handedness of father: left ____ right ____ ambidextrous (explain) ____

Number of brothers: left ____ right ____ ambidextrous (explain) ____

Number of sisters: left ____ right ____ ambidextrous (explain) ____

I am adopted and do not know the handedness of my biological parents ____
APPENDIX C - MEDICAL HISTORY QUESTIONNAIRE

ID NUMBER __________________________ DATE ____________

The following information is needed to insure that you have no medical problems which may interfere with your ability to participate in an EEG experiment. The information provided below will be treated confidentially. No names are associated with this information.

Since birth have you ever had any medical problems?
yes__ no__
If yes, what?

Have you ever hit your head and lost consciousness?
yes__ no__
If yes, explain:

Did you ever have problems where you felt it necessary to see a counselor, psychologist, or psychiatrist?
yes__ no__
If yes, explain:

Have you ever been hospitalized?
yes__ no__
If yes, explain:

Please list any medications which you are currently taking on a regular basis.
Do you have, or have you ever had, any of the following?
(check if so)
___ strong reactions to cold weather
___ circulation problems
___ tissue disease
___ skin disorders
___ arthritis
___ asthma
___ allergies
___ diabetes
___ heart problems
___ phobia/very strong fear
___ fear of small places
___ severe head injury
___ learning disability
___ hyperactivity
___ difficulty concentrating
___ epilepsy
___ frequent episodes of passing out
___ frequent severe headaches
___ frequent memory lapses
APPENDIX D - GROUP NECKER CUBE TEST

The Necker cube is a two-dimensional drawing which appears to a viewer as a three-dimensional cube. As a viewer continues to look upon the drawing, the orientation of the cube will appear to shift. The back of the cube will become the front and visa versa. These apparent shifts in orientation are called reversals.

On the next page is a drawing of a Necker cube with a dot (fixation point) at the center. When instructed to by the experimenter, turn the page and look upon the drawing, focusing on the fixation point. Your task will be to focus upon the dot, and observe and record any reversals. Reversals may be from back to front or front to back. You will record reversals by checking with a pencil or pen anywhere on the rectangular score sheet. Position the rectangular score sheet directly below these instructions and place the tip of your pen or pencil on the score sheet before turning the page.

There will be a two-minute familiarization trial of this test, followed by three one-minute experimental trials. When instructed to by the experimenter, turn the page, look at the fixation point on the Necker cube and begin recording reversals as you see them. At the end of each trial, when signaled by the experimental, cover the drawing back up with these instructions. Remember, the first trial doesn’t count and you may ask questions if you are not sure about what a reversal is.

Please report as accurately as possible. Neither few nor many reversals is indicative of intelligence level.
APPENDIX E

EEG/NECKER CUBE EXPERIMENTAL PROTOCOL

I. Meeting subject
   A. Greet subject.
   B. Place subject’s books and/or jacket.
   C. Seat subject in brown chair.
   D. Ask subject to fill out consent form.

II. Electrode application
   A. Pull on rubber gloves.
   B. Measure and mark for electrode placement.
   C. Clean electrode sites with skin prep.
   D. Apply electrodes.
   E. Assure that impedances are below 5 kOhm.
   F. Position subject so that center of eyes is 70 cm
      from and level with the center of the monitor while placing
      a towel behind the subject’s neck.
   G. Pull drawer out over the subject’s legs. Place
      board and keyboard over the drawer.
   H. Tell subject you will check their brainwaves for
      artifact. Turn on the polygraph and check for artifact.
      Eliminate as much as possible. Turn off polygraph.

III. General Instructions
     "You will be given a series of instructions on the
     computer monitor and shown presentations of a fixation point
     by itself and the Necker cube with a fixation point. To
     standardize the experiment, I will read the instructions
     with you and answer any questions you may have. After a
     frame of instructions you will be asked to hit the enter key
     at my signal. I will tell you to hit the enter key by
     saying ready, enter. When I say ready, position your finger
     over the enter key. When I say enter hit the enter key and
     place your hand back in your lap. Do you have any questions
     now? Okay, then I will start the program."

     Start the program. Position the cursor off the screen
     and tape it into position. Place the cursor on the chair
     beside the subject. Ask the subject to enter their name and
     ID number.

IV. Baseline Instructions
     "Welcome! Thank you for participating in this study.
     The purpose of this experiment is to investigate the
     neurological processes involved in visual perception. You
     will be shown presentations of the Necker cube Illusion.
     This is a two-dimensional drawing that appears to be three-
     dimensional to the viewer. As a person continues to look
     upon the drawing, the orientation of the cube will appear to
     shift. The front of the cube will appear to shift to the
     back and the back will appear to shift to the front. These

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apparent shifts are called reversals.

You will be looking at the Necker cube under two
different conditions that will be described to you by the
experimenter. Each experimental condition will consist of
six one-minute trials. While you are looking at the Necker
cube, a record of your brainwaves will be made.

To better understand how the Necker cube illusion
affects your brainwaves, we must first take a baseline of
your brainwave activity while you are looking at a very
simple stimulus. When you press the "ENTER" key a dot will
appear at the center of the screen. This dot is called a
fixation point. Concentrate on the fixation point. Do not
look at anything else, or move your head in any way. You
will be looking at the fixation point for three one-minute
trials. There will be a brief rest between trials. This
procedure will be repeated after the Necker cube conditions.

Tell the experimenter when you are ready to proceed.
Do not press the "ENTER" key until told to do so by the
experimenter."
"Any questions? "Okay, just relax while I adjust the
equipment"

V. Baseline 1-3
A. Mark the polygraph record with subject ID number and
condition (e.g. 1234BAS1).
B. Turn on the polygraph and check for artifact.
C. Ask subject if ready.
D. Say "ready, enter."
E. As you say enter start the stopwatch.
F. When stopwatch reaches 15 seconds, hit the R key.
G. After trial, turn off polygraph, tell the subject to
relax.
H. Save the buffer.

VI. Passive Condition Instructions
"The Necker cube is a two-dimensional drawing that
appears to be three-dimensional to the viewer. As the
viewer continues to look upon the drawing, the orientation
of the cube will appear to shift. The front of the cube
will appear to shift to the back and the back will appear to
shift to the front. These apparent shifts are called
reversals.

When you press the enter key, a Necker cube will be
presented. Look at the Necker cube until you are sure you
understand what a reversal is. You may ask the Experimenter
if you have any questions while looking at the screen. You
may proceed when you are ready by pressing the enter key."
A. Tell the subject to press enter.
B. Allow the subject to look at the Necker cube for one
minute.
C. Ask for questions.
D. Tell subject to hit enter.

"During this condition, you will signal when you see a reversal by using the mouse button. Hold the mouse in the center of your lap by using both hands and position both thumbs over the button. The experimenter will demonstrate. When you see a reversal, press the mouse button with both thumbs simultaneously. Reversals may be in either direction, front to back, or back to front. Reversal frequency is not related to intelligence. There will be six one-minute trials in this condition.

When you press the enter key a Necker cube with a fixation point in the center will appear. Focus upon the fixation point. Do not move your eyes away from the fixation point and keep your head as still as possible. Hold the mouse in the center of your lap and do not move it around. When you see a reversal, signal by pressing the mouse button.

Tell the experimenter when you are ready to proceed. Do not press the enter key until told to do so by the experimenter, then place you hand back into position on the mouse."

E. Ask for questions.

VII. Passive Condition 1-3
A. Mark the polygraph record with subject ID number and condition (e.g. 1234PAS1).
B. Turn on the polygraph and check for artifact.
C. Ask subject if ready.
D. Say "ready, enter."
E. After trial, turn off polygraph, tell the subject to relax.

F. Remark the polygraph record.

VIII. Passive Condition 4-6
A. Mark the polygraph record with subject ID number and condition.
B. Turn on the polygraph and check for artifact.
C. Ask subject if ready.
D. Say "ready, enter."
E. As you say enter start the stopwatch.
F. When stopwatch reaches 15 seconds, hit the R key.
G. After trial, turn off polygraph, tell the subject to relax.
H. Save the buffer.

IX. Active Instructions

"In this condition, you will be attempting to force the reversals to occur. The following instructions will be repeated to you verbally by the experimenter as you are looking at the next screen.

When you press the enter key, a Necker cube will appear with two of the angles labeled A or B. Without moving your
eyes away from the fixation point, focus your attention on Angle A. After a moment, Angle A should seem to appear at the front of the cube. Without moving your eyes, focus your attention on Angle B. A reversal should occur as Angle B appears to shift to the front of the cube while Angle A shifts to the back. Practice causing the reversals to occur by alternating you attention from one angle to the other without moving your eyes from the dot at the center of the cube.

You will not be timed or scored on the next screen. The experimenter will repeat these instructions, and answer any questions that you may have. Press the enter key when you are ready to proceed."

A. Tell subject to hit enter.

"Now without moving your eyes away from the fixation point focus your attention on angle A. After a moment, Angle A should seem to appear at the front of the cube. Let me know when it has. Now, without moving your eyes, focus your attention on angle B. A reversal should occur as Angle B appears to shift to the front of the cube while Angle A shifts to the back. Let me know when that happens. Practice causing the reversals to occur by alternating your attention from one angle to the other without moving your eyes from the dot at the center of the cube.

B. Allow subject to practice for one minute.
C. Ask for questions.
D. Tell subject to hit enter.

"When you press the enter key you will be shown a Necker cube with a fixation point at the center. Angles A and B are in the same positions but not labeled. Try to cause as many reversals as you can by alternating your attention between the two angles without moving your eyes from the fixation point.

Signal the reversals by clicking the mouse button as previously instructed. Do not move your head. Keep the mouse positioned at the center of your lap. There will be six one-minute trials in this condition.

Tell the experimenter when you are ready to proceed. Do not press the enter key until told to do so by the experimenter, then place your hand back into position on the mouse.

X. Active Condition 1-3

A. Mark the polygraph record with subject ID number and condition (e.g. 1234ACT1).
B. Turn on the polygraph and check for artifact.
C. Ask subject if ready.
D. Say "ready, enter."
E. After trial, turn off polygraph, tell the subject to relax.
F. Remark the polygraph record.

XI. Active Condition 4-6
   A. Mark the polygraph record with subject ID number and condition.
   B. Turn on the polygraph and check for artifact.
   C. Ask subject if ready.
   D. Say "ready, enter."
   E. As you say enter start the stopwatch.
   F. When stopwatch reaches 15 seconds, hit the R key.
   G. After trial, turn off polygraph, tell the subject to relax.
   H. Save the buffer.

XII. Final Baseline Instructions
    "To see if looking at the Necker cube is still influencing your brainwaves, we must repeat the procedure of looking at only a fixation point. When you press the enter key, a fixation point will appear. Concentrate on the fixation point while keeping your head still. There will be three one-minute trials of this condition.
    Tell the experimenter when you are ready to proceed. Do not press the enter key until told to do so by the experimenter."

XIII. Baseline 4-6
   A. Mark the polygraph record with subject ID number and condition.
   B. Turn on the polygraph and check for artifact.
   C. Ask subject if ready.
   D. Say "ready, enter."
   E. As you say enter start the stopwatch.
   F. When stopwatch reaches 15 seconds, hit the R key.
   G. After trial, turn off polygraph, tell the subject to relax.
   H. Save the buffer.
   I. After last trial, have subject hit enter for "thank you screen."
   J. Unhooking subject
   K. Remove electrodes from subject.
   L. Dampen washcloth in bathroom.
   M. Wash away all electrode paste and visible marks.
   N. Thank subject and answer any questions.
   O. Give subject initial portion of polygraph record used for artifact management.

XIV. Preparation for next subject
   A. Wash electrodes in bathroom with brush and warm water.
   B. Disinfect electrodes with solution of 1:20 bleach and water.
   C. Install electrodes into junction box.
   D. Place used towel and washcloth into linen bag.
VITA

Timothy Floyd Knebel June, 1993
1. Personal Data

   Address:  3110 Meadowbrook Drive, #25
             Blacksburg, VA 24060

   Home Phone:  (703) 951-3265

   Business Phone:  (703) 231-6520

   Birthdate:  Feb. 26, 1957

2. Education

   Aug. 1990-Present  Virginia Polytechnic Institute and
                      State University
                      MS Program in Applied-Experimental
                      Psychology

   May 1990, B.S.  Virginia Commonwealth University
                     Major: Psychology
                     Honors: National Dean’s List
                     Top One-Percent Humanities
                     and Sciences Academic Award

   May. 1979, B.A.  James Madison University
                     Major:  English
                     Minor:  Biology

3. Research Experience

   Aug. 1990-Present  Graduate Researcher
                      Cognitive Processing Laboratories
                      Department of Psychology
                      Virginia Polytechnic Institute and
                      State University, Blacksburg, VA 24060

                      Involved in ongoing research on the
                      electrophysiological (EEG)
                      correlates of sustained attentional
                      task performance as mediated by
                      individual differences in
                      cognitive abilities.

                      Supervisor: Helen Crawford, Ph.D.
4. Teaching Experience

Fall 91 / Fall 92  Instructor for Laboratory in Sensation and Perception

Designed, prepared, and taught laboratory classes in classical psychophysics, signal detection, static and dynamic visual acuity, pitch perception and audibility curves, olfactory sensitivity, and visual illusions.

Spring 92 / Spring 93  Instructor for Laboratory in Physiological Psychology

Designed laboratory classes in psychophysiology. Taught students to apply electrodes and operate Coulbourne modular amplifiers, oscilloscopes, and Lexicor EEG machines. Students measured GSR, EMG, skin temperature, blood flow, EKG, heart rate, EEG, and VEP.

Fall/ Spring 1990/91  Teaching Assistant, Introductory Psychology
Virginia Polytechnic Institute and State University, Blacksburg, VA 24060

Responsible for discussion classes of about thirty students each.

5. Work Experience

April 92-Current  EEG Technician
Lewis-Gale Hospital
Salem, VA

Perform clinical electrophysiological assessments including EEG, as well as visual and auditory evoked potentials. Operate Grass, Teca, and Nihon/Kohden equipment.
May 91 - April 92

PSG/EEG Technician
Radford Community Hospital
Radford, Virginia

Performed sleep study assessments (polysomnographies) and clinical electroencephalograph tests. Operated a Nihon/Kohden polygraph machine.

July 1980-Aug., 1990

Manager
Bill's Barbecue, Inc.
Richmond, VA 23230

Held position of store manager before returning to school. Supervised about twenty employees including an assistant manager. Responsible for hiring, training, and scheduling. Ordered supplies and coordinated maintenance. Part-time relief manager while attending VCU.

May 1979-Jan. 1988

Army Reserve Officer
301st Signal Company,
Lawrenceville, VA, 300th Support Group, Fort Lee, VA

Held positions of assistant group signal officer, platoon leader, and executive officer. Trained and supervised troops in electronic communications. Resigned as Captain.

Part-time jobs while attending school included: dishwasher, grill cook, laborer, carpenter's assistant.
6. **Presentations**

**August 1992**

**September 1992**

**October 1992**

**October 1993**

7. **Professional Associations**

**Dec. 1990-Present**
American Psychological Association

**Signature:**
Timothy F. Knebel, June, 1993