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A Measurement Model for Spectral Analyzed EEG

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A MEASUREMENT MODEL FOR SPECTRAL ANALYZED EEG

BY

MICHAEL DAVID WEILER

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE

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ABSTRACT

The purpose of this study was to determine whether linear combinations of absolute-power beta waves were predictive of changes in vigilance. Spectral analyzed EEG data were collected across eight bipolar sites from 102, right-handed adults during a resting condition and during an auditory continuous performance test. The most normal distribution of absolute power (AP) scores was produced by a $\log_{10}(\text{AP})$ transformation and the most normal distribution of relative power (RP) scores was produced by a $\log_{10}(\text{RP}/1-\text{RP})$ transformation. Absolute power had greater short-term reliability than relative power.

Components were derived from Principal Components Analysis performed on AP, RP, $\log_{10}(\text{AP})$, and $\log_{10}(\text{RP}/1-\text{RP})$. A component comprising frontal, RP theta was negatively correlated with omission errors. Changes in components comprising right-sided, AP beta were negatively correlated with changes in omission errors. Changes in frontal, AP beta and posterior, RP theta components were positively correlated with changes in omission errors. None of the multiple regression equations using these components, however, accounted for more than 13% of the variance. Right-sided and frontal AP beta components appeared, however, to warrant a follow-up study for purposes of cross validation. The AP, 12-component solution provided the best model of EEG activity during a vigilance task.

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Introduction

The primary purpose of this study was to determine whether linear combinations of spectral analyzed electroencephalograms (EEG), specifically, linear combinations of absolute-power beta waves, were predictive of changes in attention and verbal information processing.

The following review begins with an examination of previous research pertaining to: (a) vigilance tasks and their relationship to brain activity, (b) brain activity and its relationship to EEG, and (c) vigilance tasks and their relationship to EEG. Ongoing measurement questions within the field of EEG research and a model for investigating those questions is then proposed. Finally, predictions are specified regarding: (a) the outcome of the measurement questions, and (b) the manner in which changes in levels of vigilance relate to EEG.

Vigilance and Brain Activity

Attention often is differentiated into selective and sustained operations. Vigilance refers to the sustained aspects of attention. A vigilance decrement is taken to mean the reduction in level of performance associated with time on task and thus is distinguished from the overall level of performance (Parasuraman, 1984).

The modern study of vigilance dates back to World War II. It started with the observation of attentional lapses among radar operators whose job it was to detect infrequent events under monotonous conditions. Controlled

laboratory studies of vigilance began with the work of Mackworth (1948). His research confirmed the suspicion that sustained attention decreased rapidly during monitoring tasks. This pattern was seen for both auditory and visual monitoring tasks (Warm, 1984).

The literature suggests that the most appropriate measures of the vigilance decrement are either the drop in the number of correct signal detections or the increase in response time to signals (Warm, 1984). In many vigilance tasks the decrease in the detection rate is also accompanied by a decrease in commission errors (i.e., false alarms). The decrease in detection efficiency associated with time on task could be explained by signal detection theory (Swets, Tanner, & Birdsall, 1961), either by parameters of sensitivity (i.e., the person's ability to distinguish between targets and non-targets) or response bias (i.e., the willingness to call an ambiguous signal a target). It has been demonstrated that a sensitivity decrement can be produced under conditions where the stimulus rate is high and the task has memory demands, that is, the individual must compare stimuli with earlier stimuli maintained in memory (Parasuraman, 1984).

The continuous performance test (CPT) was introduced in 1956 by Rosvold, Mirsky, Sarason, Bransome, and Beck. It was designed as a measure of vigilance or selective attention for infrequently occurring stimuli (Eliason & Richman, 1987; Haperin, Sharma, Greenblatt, & Schwartz,

1991). The original purpose of the CPT was to compare brain-damaged with non-brain-damaged individuals on their abilities to sustain attention. The individuals were to respond whenever they saw an "A" followed by an "X" (Halperin et al., 1991). CPTs subsequently have been used in a number of ways. For example, evoked response potentials (ERPs) have been collected while participants performed CPT tasks. Here, Herning, Hooker, and Jones (1987) demonstrated that cocaine altered particular aspects of ERP wave forms (i.e., N 100 and CNV amplitudes). However, Friedman, Cornblatt, Vaughan, and Erlennmeyer-Kimling (1986) found that ERP collected during CPT did not distinguish among normal controls, psychiatric controls, and children at risk for schizophrenia. CPTs have been used to differentiate referred from non-referred children. O'Dougherty, Nuechterlein, and Drew (1984) were able to distinguish children with Attention-deficit Hyperactivity Disorder from normal controls. Eliason and Richman (1987) demonstrated that learning-disabled children made more omission errors and had slower reaction times than a matched control group. Despite the empirical support, CPTs have not proven to be clinically useful. CPT performance does not reliably distinguish between clinical groups nor do all members of any group consistently perform at any particular level (Halperin et al., 1991).

A variety of indexes has been suggested to describe performance on the CPT including: the Omission Error Index (I_o = omission errors/omission opportunities), the Detection Index ($P(D) = 1 - I_o - C_o$; where C_o = commission errors/commission opportunities), and the Error Index ($I_o + 2C_o$). The commission error ratio is doubled in the last index because, among the brain-injured population, errors of commission are considered more serious than errors of omission (Pigache, 1976). D' also is used in CPT work. D' is derived from signal detection theory and is defined as the z score distance between $1 - I_o$ and C_o or $d' = F(\text{hits/targets}) - F(\text{false alarms/non-targets})$ where F is equal to the z score probability (Herning et al., 1987). In classification studies, significant findings have been reported when using correct responses (Eliason & Richman, 1987; Friedman et al., 1986; Grant et al., 1990; Halperin et al., 1991), d' (Herning et al., 1987), false alarms, and reaction times (Halperin et al., 1991) as dependent variables.

Gordon and Mettelman (1988) demonstrated high test-retest reliabilities in a nine-minute vigilance task where the participants were requested to press a button every time they saw a "9" preceded by "1." Here, 32 children were retested between 2 and 22 days after the initial administration. The test-retest correlation for total correct was .72; for total commissions it was .84. Another 20 children were retested at one year.

Correlations for total correct dropped to .68 and total commissions rose to .94. All correlations were significant at the $p < .001$ level.

In the present study, short-term (i.e., six-minute) and longer term (i.e., one-week) test-retest correlations were calculated to assess the stability of the CPT performance measures and to permit the identification of the most reliable index for use as the criterion in the multiple regression equations. It was predicted that reliabilities would exceed .80 and that the detection index would have the highest test-retest reliability score.

Positron Emission Tomography and Brain Activity

Petersen, Fox, Posner, Mintun, and Raichle (1988) used Positron Emission Tomography (PET) to measure blood flow in the brain during processing of visually and auditorily presented words (i.e., a non-CPT activity). During auditory processing, bilateral activity was seen in the primary auditory cortex. Activation also was seen on the left side in the temporo-parietal cortex, anterior superior temporal cortex, and the inferior anterior cingulate cortex.

In another study (Cohen et al., 1987), PET was recorded after 35 minutes of eyes-closed CPT. Twenty-seven healthy adults pressed a hand-held response button whenever the lowest of three 500 Hz tones sounded. Cohen et al. (1987) reported a significant ($p < .05$, uncorrected

for the 55 comparisons) negative Pearson product-moment correlation between metabolic rate in middle pre-frontal cortex and false alarms. This negative relationship showed that higher relative (region/global) metabolic rates were associated with fewer false alarms. Relative metabolic rate was uncorrelated with hits in this area.

Buchsbaum et al. (1990) used PET to compare relative glucose use (mean/whole-slice mean) between no-task (visual fixation on flashing stimuli) controls and visual-CPT-task (pressing a button whenever a "0" was presented) controls. Occipital metabolic rates between the two groups were comparable. There were metabolic increases in the right frontal and right temporo-parietal regions associated with task performance. The participants who performed the best on the CPT had higher relative metabolic rates in the right parietal area.

Brain Activity and EEG

According to Matejcek (1982), much is still unknown about the relationship between brain activity and EEG. EEG records brain activity on the surface of the cerebral cortex (Buchsbaum, Coppola, & Cappelletti, 1982; Matejcek, 1982). A scalp EEG does not detect electrical activity from deep structures nor from the approximately two thirds of the cerebral cortex that lie within sulci. It is known, however, that the amplitude of scalp EEG depends on: (a) the number of synchronously firing neurons, (b) the neuroanatomical structure in which the neuron is located,

and (c) the distance between the neurons and the recording electrode (Matejcek, 1982). Homan, Herman, and Purdy (1987) demonstrated that for most individuals, a standard 10-20 electrode-placement system provides reliable localization of the underlying cortical structures.

Vigilance and EEG

Many studies of vigilance and brain wave activity have noted a relationship between performance and EEG activity in the alpha (7 to 13 Hz) and theta (3 to 7 Hz) frequency bands. In one study, participants performed a radar-detection simulation for a two-hour period. Relative EEG power was recorded from occipital and parietal lobes. The decrease in detection accuracy with time was shown to be associated with increases in alpha and theta activity and decreases in beta activity (Davies & Parasuraman, 1982; Parasuraman, 1984). The electrode arrangement used in this study did not allow an examination of the parietal areas of the brain.

Researchers have noted changes in EEG power associated with changes in levels of cortical arousal (Parasuraman, 1984). In both head-injured and non-head-injured control individuals, Randolph and Miller (1988) noted that heightened states of arousal were associated with increases in delta and beta activity and decreases in alpha and theta activity. Matejcek (1982) reported a number of studies that associated relaxed wakefulness with alpha activity and alert attentiveness with beta activity.

Figure 1. International (10-20) electrode placement placement and format of PCA figures.

Figure 1 illustrates the electrode placement used in this study. Because of the auditory information processing demands of the CPT task, increases (in comparison with resting EEG) in beta activity in channels 3 and 5 on the left side and 6 on the right were anticipated. Further, beta increases (over resting EEG) in regions 1, 2, and 4 associated with the attentional aspects of the CPT also were expected. The overall pattern of change between the resting condition and the CPTs was expected to show increases in the levels of delta and beta activity and decreases in the levels of alpha and theta activity.

Finally, the attentional characteristics of the current investigation (i.e., memory load and rapid event rate) were expected to produce a sensitivity decrement over time. This sensitivity decrement was expected to be associated with an increase in occipital theta and alpha activity, and a decrease in occipital beta activity. Based on the previously cited PET studies, it also was expected that beta activity in the right frontal (channel 2) and right fronto-temporal (channel 4) regions would be negatively correlated with decreases in vigilance.

Normality of Absolute-Power Distributions

Complex wave forms recorded during an EEG are separated into a series of simpler sine-wave frequency patterns (or wave bands); the area bounded by these sine waves (i.e., one half amplitude squared) is termed

absolute-power. For each EEG channel (corresponding to a single hemisphere's cortical region), relative power is calculated by dividing the absolute power of a particular wave band by the sum of the absolute powers of all the wave bands at that region. Previous studies have examined and transformed EEG data collected during resting conditions in a variety of ways. There is consensus that, for EEG collected during resting conditions, a log transformation produces the most normal distributions of absolute-power variables and that a $\log(x/(1-x))$ normalizes relative power distributions (Amador et al., 1989; Gasser, Bacher, & Mocks, 1982; John et al., 1988; Oken & Chiappa, 1988; Pollock, Schneider, & Lyness, 1990). There may be some waveband differences, however, that influence these generalizations. For instance, Pollock et al. (1990) reported that absolute-theta amplitude was not normalized with the log transformation. Moreover, Oken and Chiappa (1988) found that relative power had fewer skewed results than absolute power. Among absolute-power variables, the delta band had the most skewed variables and the beta2 band variables were least skewed.

The present study examined seven transformations selected from a review of earlier EEG studies (Amador, Sosa, Marqui, Garcia, Lirio, & Bayard, 1989; Gasser, Bacher, & Mocks, 1982; Oken & Chiappa, 1988; Pollock, Schneider, & Lyness, 1990): $\log_{10}(AP)$, $\log_{10}(1+AP)$, square root(AP), cube root(AP), and $1/\text{square root}(AP)$ for

absolute-power (AP); and arc-sin square root(RP) and $\log_{10}(RP/(1-RP))$ for relative power (RP). It was predicted that $\log_{10}(AP)$ and $\log_{10}(RP/(1-RP))$ transformations would result in the most normal distributions of EEG variables collected during a CPT.

Skewness and kurtosis of the seven transformations were examined by calculating the number of variables exceeding critical values for skewness and kurtosis after correcting for family-wise errors (Stevens, 1986). Using the multiple-regression procedure noted previously, absolute-power scores, relative-power scores, and the most normal distributions of absolute-power and relative-power scores were contrasted on their accuracy in predicting criterion scores. As before, it was predicted that the non-transformed absolute-power variables would explain more of the variance than the other options and significantly predict performance.

Absolute vs. Relative Power

There is disagreement in the scientific literature as to whether absolute power or relative power better reflects measures of EEG cerebral functioning. The choice of using either relative power or absolute power in an analysis is significant because varying outcomes may result depending on the metric used (Byring, Salmi, Sainio, & Orn, 1991; Randolph & Miller, 1988).

Relative-activity measures are used in other fields of brain research as well as in EEG studies. For example,

in PET research, investigators standardize absolute glucose metabolic variables by dividing regional glucose metabolic rates by global glucose metabolic rates, thereby attempting to adjust for inter-individual variation (Cohen et al., 1987).

John and his colleagues (John et al., 1977; John, Ahn, & Prichep, 1980; John, Prichep, Fridman, & Easton, 1988), reported that absolute-power measures were less reliable than indexes of relative-power. In contrast, Fein et al. (1983) demonstrated that, among their sample of children, absolute power was as reliable a measure of resting EEG activity as relative power. They also noted that changes in relative-power measures were difficult to interpret because of the correlations between the scores. As an example, a decrease in a relative-power waveband may be the result of a decrease in the power of that waveband, an increase in power in other wavebands, or a combination of these two processes (Fein et al., 1983). Fein et al. (1983) argued it would be difficult to imagine a situation that simultaneously would produce instability of the individual wave bands (i.e., absolute-power reliability) yet, at the same time, greater stability in the relationship between bands (i.e., relative-power reliability).

Pollock et al. (1991) examined Pearson product-moment correlations for log-transformed relative amplitude and log-transformed absolute amplitude. They used this

statistic because they felt that amplitude met the assumptions of a parametric statistic (i.e., amplitude was a ratio scale and a log transformation normalized the distributions). At four and one-half months, most test-retest reliabilities were in an acceptable range although delta reliability tended to be low. They suggested that, for samples similar to the one they studied (i.e., healthy older individuals), absolute-power rather than relative-power measures would be preferable.

Gasser, Bacher, and Steinberg (1985) examined ten-month test-retest reliability on a sample of children using the non-parametric Spearman rank-order correlation. On the average, absolute and relative power were similarly reliable. They found higher beta-band reliability in relative power compared to absolute power. Reliability was comparable in the alpha and theta bands. In the delta wave band, absolute-power reliability was low but higher than relative-power reliability.

In the present study, absolute power and relative power were contrasted in four ways. First, short-term (i.e., six-minute) test-retest reliability of absolute-power and relative-power variables was compared. Second, consistency in the relationship of absolute- and relative-power variables across groups was compared using a double cross-validation procedure. Third, the effect of the interdependence of relative-power scores on reliability was explored. It was proposed that the reliability of any

relative-power waveband would be limited by the lack of reliability in other bands. Therefore, removal of the most unreliable waveband from the calculation of relative power would result in increased test-retest reliabilities for the remaining wavebands. Fourth, the capacity of relative-power and absolute-power variables to predict performance was contrasted. Components derived from principal components analyses (PCA) of absolute- and relative-power variables were entered into a standard multiple-regression equations with performance scores on an auditory CPT as the criterion. It was predicted that a multiple-regression equation based on components derived from the absolute-power PCA would better predict performance and explain more of the variance than components from the other transformations.

Principal Components Analysis

Principal components analysis (PCA) has been used in the past to investigate brain-wave activity (Amador et al., 1989; Bente, 1979; Friedman, Cornblatt, Vaughan, & Erlenmeyer-Kimling, 1986; Gasser, Jennen-Steinmetz, Sroka, Verleger, & Mocks, 1988; Gasser, Mocks, & Bacher, 1983; Ott, McDonald, Fichte, & Herrmann, 1982; Schenk et al., 1982). For example, Bente (1979) reported an attempt to minimize vigilance fluctuations during EEG recording by requiring participants ($N = 12$) to perform a visual-tracking task under placebo and drug (Viloxazine) conditions. Although the procedure was not described

explicitly in this report, it appeared that EEG was recorded from the right occipital region, and that the 32, 1-Hz relative-power spectral variables were analyzed using a PCA with a varimax rotation. Bente's PCA produced five factors with positive (+) and negative (-) loadings: F1 30 Hz (+); F2 9 Hz (+) and 3 Hz (-); F3 13 Hz (+); F4 17 Hz (-); and F5 7 Hz (+) and 11 Hz (-). These factors explained 91% of the variance. Bente (1979) also performed a PCA on resting EEG. He compared factor scores obtained under placebo and Viloxazine conditions using Hotellings T². Bente found a significant difference ($p < .01$) on a factor consisting of 2 to 6 Hz (+) and 10 Hz (-) EEG. He suggested that this factor could be interpreted as a vigilance factor.

Ott et al. (1982) recorded eyes closed resting EEG from the O2-A2 (right occipital - right ear) channel on 60 males between the ages of 21 and 45. Twenty minutes later, the same participants completed a series of six behavioral tests of reaction time, visual sensitivity, continuous addition, and manual dexterity. Ott et al. performed a PCA on the six behavioral measures and seven EEG parameters (total power and relative-powers of theta, alpha1, alpha2, beta1, and beta3). Using a criterion of eigenvalue greater than 1 and a varimax rotation, they identified a four-factor solution accounting for 65% of the variance. The first factor (27% of the variance) consisted of delta (1.5 hz to 6.0 Hz), negative alpha1

(8.5 Hz to 10.5 Hz), Beta1 (12.5 Hz to 18.5 Hz), Beta3 (21 Hz to 30 Hz), and negative total power. The second and third factors (30 % of the variance) consisted of the behavioral measures. The fourth factor (8% of the variance) consisted of theta (6.0 Hz - 8.5 Hz) and negative alpha2 (10.5 Hz - 12.5 Hz). The absolute values of all loadings were greater than or equal to .60. The correlation between EEG variables and the behavioral measures were low ($r_{\max} = -.28$) explaining less than 8% of the variance.

Schenk et al. (1982) calculated factor and component scores on absolute-power EEG collected during free-floating vigilance conditions (i.e., resting without stage B sleep). Their variables consisted of 34, 0.95-Hz frequency bands between 0.5 Hz and 32.8 Hz, collected on 41 participants, from two bipolar EEG leads (C4-P4, P4-O2). They identified an identical five-factor solution for both factor analysis and PCA that accounted for 85% of the variance. Factor 1 consisted of fast alpha (10 Hz to 13.8 Hz) and medium beta (19.5 Hz to 24.5 Hz), and accounted for 20% of the variance. Factor 2, a broad band factor, consisted of fast delta-theta (2.4 Hz to 9.05 Hz) plus slow alpha-slow beta (13.8 Hz to 18.55 Hz), and accounted for 24% of the variance. Factor 3 consisted of fast beta activity (22.35 Hz to 31.85 Hz), and accounted for 24% of the variance. Factor 4 consisted of delta activity (.05 Hz to 3.35 Hz), and accounted for 9% of the

variance. Factor 5 consisted of slow to medium beta (16.65 Hz to 19.5 Hz), and accounted for 7% of the variance. They went on to examine test-retest reliability for the factor scores at 1, 2, 3, and 4 hours. Factors 1 and 2 were stable with correlation coefficients ranging from .81 to .92. The delta factor was unstable at the P4-O2 lead. Test-retest reliabilities were calculated on the same participants at four separate days. Factor 1 reliability ranged from .57 to .87, factor 2 from .09 to .65, factor 3 from .75 to .87, factor 4 from .23 to .55, and factor 5 from .59 to .81.

In 1983, Gasser, Mocks, and Bacher, investigating mental retardation and learning disability in children, recorded eyes-closed resting EEG from eight locations (F4, F3, C4, C3, Cz, Pz, O2, O1 with linked earlobe reference) and six bands in both absolute and relative power. They attempted to reduce the set of 48 variables by performing a PCA for each band, in both absolute and relative power, using the recordings from the eight locations as variables. Based on their normative group of 31, 10 to 13 year olds, they decided on a three-factor solution (explaining 95% of the variance) for reasons of interpretability. They did not rotate the axes further because it eliminated the first factor as a general topographic factor. The first factor (81.9% of the variance) appeared to be a general spectral band across-all-locations factor, the second (9.4%) discriminated

anterior from posterior locations, and the third (3.2%) discriminated frontal from central and parietal locations. There were few differences between the absolute-power and relative-power solutions. Compared to absolute-power, relative-power scores had lower loadings on factor 1, but higher loadings on factors 2 and 3. Gasser and his colleagues (1983) went on to replicate an earlier classification study in which the 48 individual parameters had been used. When they replaced the 48 variables with the 18 factor scores (three factors by 6 bands) the results were identical. Greater parsimony was achieved without any significant loss of information.

In 1988, Gasser et al. replicated their earlier study using 158 children and adolescents between 6 and 17 years of age. This time they restricted the PCA to three- and four-component solutions explaining 95% of the variance. In the two solutions the first three factors were identical. The third and fourth components accounted for approximately 2.5% and 2% of the variance, respectively. The fourth component discriminated the left from the right hemisphere for some of the bands.

In the present study, a PCA was performed on absolute-power variables, relative-power variables, and the most normal transformations of absolute-power and relative-power variables. The axes were rotated orthogonally (using a varimax rotation). Component scores were generated by unit weighting normalized deviation

scores. Short-term test-retest reliabilities were calculated for these component scores by comparing the two minutes of artifact-free EEG data collected, starting at the 45th second of the continuous performance test (CPT1), with the two minutes of artifact-free EEG data collected, starting at the 405th second (CPT2) of the task. These orthogonal component scores were used in multiple-regression equations to predict performance scores. It was predicted that the PCA would allow the 40 variables to be reduced to a smaller set of components (i.e., less than 10), that these components would be reliable (i.e., test-retest reliabilities greater than .80), and that they collectively would predict performance.

Significance of the Study

The present study differs from previous research in a number of important ways. First, EEG was collected during a CPT condition rather than during a resting condition. It was expected that the CPT condition would standardize the participants' mental state and thus provide a more stable format for comparing relative-power and absolute-power reliability. The present study did not test the assumption that CPT provided more stable EEG scores than a resting condition. It did however, contrast relative-power and absolute-power reliability, and these results were compared to those results from other studies obtained during a resting condition. Second, the study allowed a rudimentary comparison of EEG and PET findings. PET

studies have localized activity to particular areas of the brain during verbal tasks and during CPTs. The results of this study indicated whether, at the sites used in the present study, scalp EEG was sensitive to similar kinds of brain activity. Third, this study was unique in EEG literature in terms of providing a homogeneous group with an adequate sample size for conducting a PCA. EEG was collected from a variety of cortical regions and all wavebands were analyzed simultaneously. Finally, the study provided a mechanism for identifying the EEG components that were associated with attention and vigilance.

Predictions

Because of the need to identify the optimal variables for use in the subsequent analyses, the first set of predictions concerned the psychometric properties of the variables.

1. The $\log_{10}$ transformation would normalize absolute power and the $\log_{10}(x/1-x)$ transformation would normalize relative power.

2. Absolute-power variables would be more reliable than relative-power variables.

3. Unit-weighted, normalized-deviation component scores derived from PCAs on absolute and relative-power variables would be reliable ($r_{tt} > 0.80$).

4. The detection index of CPT data would be the most reliable measure of CPT performance.

The second set of predictions concerned the relationship between EEG variables and measures of vigilance.

5. The absolute power of beta activity during CPT1 in channels 1, 2, 3, 4, 5 and 6 would increase over resting.

6. The absolute power of alpha and theta activity would decrease between resting and CPT.

7. Unit-weighted, normalized-deviation component scores from components consisting of absolute-power beta from channels 1, 2, 3, 4, 5, and 6 would be predictive of level of performance during CPT1.

8. Changes in unit-weighted, normalized-deviation component scores from components consisting of absolute-power beta from channels 2 and 4 would be negatively correlated with performance change (i.e., as the number of omission errors increases beta would decrease).

9. Changes in unit-weighted, normalized-deviation component scores from components consisting of absolute-power beta from channels 7 and 8 would be negatively correlated with performance change.

10. Changes in unit-weighted, normalized-deviation component scores from components consisting of absolute-power theta and alpha from channels 7 and 8 would be positively correlated with performance change.

Method

Subjects

Main study. Participants ($N = 102$) were selected from 298 consecutive cases drawn from an undergraduate psychology course and enrolled between October, 1989 and April, 1991. They reported no history of neurological conditions, birthing complications, or loss of consciousness greater than two minutes. Handedness was assessed using a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971). Appendix A presents the modified Edinburgh Handedness Inventory. All participants were right-hand dominant for writing their names, with laterality quotients (Oldfield, 1971) between 26 and 100 ($M = 79$, $SD = 21$). There were 66 females and 36 males, aged 17.7 years to 25.5 years ($M = 19.8$, $SD = 1.49$).

Test-retest reliability study. Participants for this study were 16 consecutive cases drawn from an undergraduate psychology course, enrolled during April, 1992. All participants were examined one week after their initial evaluations, at the same time of day, by the same team of technicians. All participants were right-hand dominant for writing their names; laterality quotients calculated from the initial evaluation ranged between 38 and 100 ($M = 78$, $SD = 17$). There were 11 females and 5 males, aged 18.5 years to 23.2 years ($M = 19.8$, $SD = 1.28$).

Apparatus

EEG activity was recorded across eight bipolar channels (impedance < 10K ohm): channel 1 = Fp1-F7, channel 2 = Fp2-F8, channel 3 = F7-T3, channel 4 = F8-T4, channel 5 = T3-T5, channel 6 = T4-T6, channel 7 = T5-O1, channel 8 = T6-O2. Figure 1 illustrates the electrode positions which are in accordance with the 10-20 International Federation of Electroencephalography and Clinical Neurophysiology system (Jasper, 1958). A spectral analysis of the brain-wave activity from each of these sites was performed using a Fast Fourier Transformation. These analyses separated the complex wave forms into a series of simpler sine-wave frequency patterns or bands (i.e., delta = 1 to 3.5 Hz; theta = 3.5 to 7.5 Hz; alpha = 7.5 to 12.5 Hz; beta1 = 12.5 to 17.5 Hz; beta2 = 17.5 to 25.0 Hz) (Matousek & Petersen, 1973). The spectral analysis was accomplished using a Sentinal-8 System designed by Axon Inc., Deer Park, NY.

CPT performance was recorded via a button held in the participant's right hand and transcribed on a paper tape. The paper tape was compared with a template of the correct responses and hand scored.

Procedure

First, the task was explained to the participants, they completed informed consent forms, and answered a questionnaire on their medical history and hand preference. They were then asked to close their eyes and

relax in a comfortable chair facing a blank wall. The lights were dimmed and 45 seconds later resting EEG data were collected. This continued until two minutes of artifact-free (on-line automatic artifacting) EEG was obtained.

Participants then listened to a computer-generated audio tape (presented from a speaker placed directly in front of them) and were instructed to press a button held in the right hand whenever a letter was presented twice in succession (CPT). Letters occurred with a sound onset-to-onset interval of 0.5 seconds. Double-letter targets occurred at random intervals with an average of ten targets per minute. Forty-five seconds after the start of the CPT, EEG data collection began for CPT1 and continued until two minutes of eyes-closed artifact-free EEG was obtained. Most participants completed this phase of the investigation after about three minutes. After 6.75 minutes of task performance, a second two-minute sample of artifact-free EEG (CPT2) was obtained.

The procedure for the reliability study was identical except that the sessions were discontinued after CPT1 was collected. Before the participants began the second session they completed the handedness inventory.

Design

This study used a multiple-regression procedure to predict a behavioral measure (level of vigilance or vigilance decrement during a CPT) from a physiological

measure (EEG collected during a CPT) (Hiscock & Kinsbourne, 1987). There is disagreement in the literature as to which variables are the most valid measures of EEG and vigilance. These variables were evaluated using criteria of short-term reliability and predictability (ability to predict the behavioral measure) for the EEG measures and short-term and long-term reliability for the behavioral measures.

PCAs were used to reduce these sets of variables to more parsimonious, orthogonal components that then were entered into standard multiple regression equations. The size of the resulting R^2 statistic was used to evaluate the extent to which the EEG components could predict performance on the CPT. The size of the zero order correlations was used to evaluate the predictability of a component within a set of components.

Results

This section begins with a description of the psychometric properties of the variables and their transformations (i.e., distribution and reliability) and the changes in brain-wave activity between tasks. The process of deriving components using a PCA and the psychometric properties of those components then is described. Finally, the results of the multiple-regression equations, which used these components to predict performance on the CPT, are reported.

Reliability of Measurements

Test-retest reliability scores were obtained for the laterality quotient and the various error indexes on the 16 participants from the test-retest reliability study. Because all these scores were normally distributed, the Pearson product-moment correlation coefficient (rtt) was used to calculate reliability. The handedness inventory was found to be reliable (rtt =.93). The reliabilities of the Omission Error Index (rtt =.37), Detection Index (rtt =.35), and Error Index (rtt =.33) were all poor but roughly comparable.

Transformation of EEG Variables

Table 1 provides a comparison of distributions of the two non-transformed and seven transformed distributions. Neither absolute-power (AP) variables nor relative-power (RP) variables were normally distributed. The $\log_{10}(\text{AP})$ transformation produced the most normal distribution of absolute-power variables. The $\log_{10}(\text{RP}/1-\text{RP})$ produced the most normal distribution of relative-power variables, although the arc sin square root of relative power was comparable with two fewer leptokurtic values and five more skewed values. Appendix B contains the descriptive statistics on the two non-transformed and seven transformed distributions.

Table 1
Skewness and Kurtosis of the Various Transformations

Transformation (N)	% Kurtotic (N)		% Skewed	
Absolute Power ^a (AP)	95%	(38)	100%	(40)
Log10(AP)	12.5%	(5)	17.5%	(7)
Log10(AP + 1)	27.5%	(11)	45%	(18)
(AP) ^{1/2}	80%	(32)	92.5%	(37)
1/(AP) ^{1/2}	17.5%	(7)	35%	(14)
(AP) ^{1/3}	62.5%	(25)	77.5%	(31)
Relative Power (RP)	35%	(14)	57.5%	(23)
Arc Sin (RP) ^{1/2}	17.5	(7)	30%	(12)
Log10(RP/1-RP)	22.5%	(9)	17.5%	(7)

Note. ^a all values greater than 0.

Stevens (1986) provides formulas for calculating critical values for skewness and kurtosis. The critical value for skewness was calculated with the formula:

$$+ z = s \{ (N + 1)(N + 3) / 6(N - 2) \}^{1/2} \quad (1)$$

where z = z score; s = skewness; and N = sample size.

The critical value for kurtosis was calculated with the formula:

$$+ z = \{ k - 3 + 6 / (N + 1) \} \{ [(N + 1)2(N + 3)(N + 5)] / [24N(N - 2)(N - 3)] \}^{1/2} \quad (2)$$

where z = z score; k = kurtosis; and N = sample size.

Because of the large number of tests (i.e., 2 tests times 40 variables) alpha was set at .0005 ($z = 3.3$).

This follows the Bonferroni procedure and yields an overall type-I error rate of .04 ($80 \times .0005$). With a

sample size of 102 the critical value for skewness (equation 1) was + .777. The critical values for kurtosis (equation 2) were calculated to be 4.30 and 1.45. The formulas used by some statistical packages to evaluate kurtosis are different than the one used here and require that 3 be subtracted from the calculated critical values (Stevens, 1986). Therefore, the critical values used for these comparison were recalculated to 1.30 and -1.55.

None of the distributions were platykurtic. For the 40 (i.e., five bands by eight channels) non-transformed absolute-power distributions, 95% (38) were leptokurtic and 100% (40) were skewed. After a $\log_{10}$ transformation, 12.5% (5) of the absolute-power distributions were leptokurtic and 17.5% (7) were skewed. For the non-transformed relative-power distributions, 35% (14) were leptokurtic and 57.5% (23) were skewed. After a $\log_{10}(x/1-x)$ transformation 22.5% (9) were leptokurtic and 17.5% (7) were skewed. Table 1 shows the number of skewed and leptokurtic variables for each of the transformations.

Reliability of Transformations

Absolute-power variables were found to be significantly more reliable than relative-power variables. Table 2 shows six-minute test-retest reliabilities for each of the 40 EEG absolute-power variables (AP), relative-power variables (RP), $\log_{10}(\text{AP})$ variables (LAP), and $\log_{10}(\text{RP}/1-\text{RP})$ variables (LRP). Reliability coefficients were calculated by correlating CPT1 scores

with CPT2 scores using both the Pearson product-moment correlation coefficient and Spearman rho. Spearman rho is the more appropriate of the two statistics because, even after transformation, the distributions were not bivariate normal (Marascuilo & McSweeney, 1977). Data for the Pearson product-moment correlation are presented to aid in comparison with previous research. Because the Spearman rho is a rank ordered test, correlations would be identical for transformed and non-transformed scores. Therefore, only two Spearman correlations were calculated: AP and RP.

Because high correlations yield non-normal distributions, the non-parametric Sign test was used to compare the four sets (i.e., 40 correlation coefficients) of Pearson product-moment coefficients and the two sets of Spearman-rho coefficients. Among the Pearson product moment correlations, AP correlations were not different from LAP correlations (two tailed $p = .749$) but were higher than RP (two tailed $p < .01$). LAP correlations were higher than RP (two tailed $p < .0001$) and LRP (two tailed $p < .01$). Spearman rho correlations of AP were higher than RP (two tailed $p < .01$).

The consistency of the absolute and relative-power variables was compared using a double cross-validation design such as illustrated in Table 3. The sample of 102 participants was divided in half. A linear regression was used on the first 51 cases predicting CPT2 scores from

CPT1 scores. This regression formula was applied to CPT1 scores from the second 51 cases. This calculated CPT2 score (CPT2') was correlated with the observed CPT2 score using Spearman's rho. This procedure was done on both AP and RP scores, resulting in two sets of correlations: CV.AP1 and CV.RP1.

In a similar fashion, a regression formula derived from the second group of 51 cases was used to calculate CPT2' in the first group. The Spearman rho correlations of CPT2' and CPT2 resulted in two sets of correlations: CV.AP2 and CV.RP2. CV.AP1 scores were not different than CV.RP1 scores (two tailed $p = .268$) but CV.AP2 scores were higher than CV.RP2 (two tailed $p < .01$).

Table 2
Six-Minute (CPT1:CPT2) Test-Retest Correlations of
Transformed and Non-Transformed EEG Variables

Variable	AP Spearman rho	RP	AP	RP Pearson r	L(AP)	L(RP)
1.Delta	.7348	.6914	.7292	.7344	.7535	.7539
2.Delta	.6125	.6231	.7305	.6160	.6698	.6206
3.Delta	.6844	.6811	.7247	.7158	.7016	.7284
4.Delta	.7196	.6744	.7407	.7288	.7516	.7460
5.Delta	.8873	.9002	.9393	.9098	.9147	.9054
6.Delta	.9191	.8399	.9422	.8637	.9309	.8762
7.Delta	.9622	.8538	.8737	.9535	.9535	.9002
8.Delta	.9357	.8542	.9317	.8620	.9457	.8610
1.Theta	.7827	.7498	.8240	.7844	.8075	.7649
2.Theta	.7574	.6682	.7758	.7015	.7719	.6829
3.Theta	.9014	.7692	.9120	.7838	.9190	.7782
4.Theta	.8278	.7566	.8725	.7703	.8769	.7642
5.Theta	.9265	.8720	.9685	.8638	.9550	.8793
6.Theta	.9361	.8748	.9412	.8635	.9542	.8760
7.Theta	.9465	.8346	.9460	.8139	.9559	.8360
8.Theta	.9480	.8466	.9347	.8422	.9501	.8538
1.Alpha	.8762	.8233	.9416	.9091	.9228	.8424
2.Alpha	.8789	.7452	.9449	.7832	.9163	.7484
3.Alpha	.9304	.8583	.9487	.9018	.9487	.8995
4.Alpha	.9436	.8285	.9472	.8507	.9539	.8458
5.Alpha	.9592	.9393	.9336	.9438	.9635	.9402
6.Alpha	.9500	.9315	.9533	.9315	.9570	.9266
7.Alpha	.9551	.9282	.9697	.9425	.9595	.9440
8.Alpha	.9358	.9183	.9047	.9173	.9374	.9131
1.Betal	.7782	.7252	.9230	.7429	.8311	.7831
2.Betal	.7829	.6348	.7939	.6450	.7869	.6756
3.Betal	.8345	.7284	.8298	.8122	.8273	.7917
4.Betal	.8085	.6939	.8333	.7181	.8097	.7844
5.Betal	.9134	.9212	.8816	.9182	.9134	.9138
6.Betal	.9024	.8826	.8889	.8982	.9109	.9000
7.Betal	.8411	.9129	.7431	.9029	.8459	.9130
8.Betal	.8910	.8747	.7409	.8863	.8811	.8891
1.Beta2	.7525	.7543	.7959	.6856	.8032	.7581
2.Beta2	.7223	.6966	.7963	.6040	.7356	.6485
3.Beta2	.7850	.8078	.8480	.7906	.8080	.8091
4.Beta2	.8007	.8011	.7534	.7355	.8062	.8023
5.Beta2	.8107	.8591	.8277	.8256	.8300	.8620
6.Beta2	.8699	.8832	.8937	.8690	.8814	.8845
7.Beta2	.7875	.8467	.6351	.8172	.7610	.8405
8.Beta2	.8161	.8714	.8509	.8759	.8471	.8881

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Betal = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table 3
Double Cross-validated Correlations of Observed and
Predicted CPT2 Scores Calculated From CPT1 Scores

Variable	Spearman rho			
	Absolute Power		Relative Power	
	1st	2nd	1st	2nd
1.Delta	.7823	.6934	.7800	.5822
2.Delta	.5951	.6231	.6299	.5862
3.Delta	.6914	.6861	.7358	.6242
4.Delta	.7037	.7605	.6992	.6538
5.Delta	.8267	.9300	.9036	.8822
6.Delta	.9207	.9102	.8500	.8168
7.Delta	.9626	.9625	.8485	.8666
8.Delta	.9454	.9147	.8393	.8609
1.Theta	.7232	.8368	.8044	.6639
2.Theta	.6829	.8232	.7375	.5819
3.Theta	.8422	.9405	.7279	.8039
4.Theta	.7218	.8905	.8186	.7068
5.Theta	.9567	.8958	.8736	.8384
6.Theta	.9448	.9259	.8912	.8576
7.Theta	.9471	.9438	.8106	.8462
8.Theta	.9411	.9535	.8633	.8226
1.Alpha	.8715	.8751	.8927	.7379
2.Alpha	.8499	.8905	.8117	.6834
3.Alpha	.9286	.9265	.8861	.8213
4.Alpha	.9318	.9542	.9074	.7829
5.Alpha	.9558	.9506	.9315	.9205
6.Alpha	.9282	.9559	.9285	.9397
7.Alpha	.9342	.9643	.9341	.9032
8.Alpha	.8907	.9488	.8969	.9341
1.Beta1	.7652	.8055	.7775	.6528
2.Beta1	.7870	.7728	.6563	.6159
3.Beta1	.8122	.8948	.6350	.8150
4.Beta1	.7761	.8358	.5741	.7931
5.Beta1	.9099	.9218	.8970	.9394
6.Beta1	.9390	.8731	.9046	.8591
7.Beta1	.8849	.8025	.9169	.9024
8.Beta1	.9161	.8813	.8461	.8936
1.Beta2	.7227	.7617	.7276	.7670
2.Beta2	.7373	.7091	.7008	.6920
3.Beta2	.7600	.8140	.7775	.8344
4.Beta2	.8003	.8032	.7552	.8266
5.Beta2	.8372	.7908	.8580	.8472
6.Beta2	.9141	.8308	.8820	.8755
7.Beta2	.7608	.7949	.8097	.8451
8.Beta2	.8306	.8107	.8693	.8816

Note. CPT1 scores were used to predict CPT2. Predicted CPT2 correlated with observed CPT2. 1st = First half of sample used to derive the regression formula. 2 = Second half of sample used to derive the regression formula.

The Effect of Unreliable Variables on Calculations of Relative Power

Removal of the four least reliable absolute-power variables from the calculation of relative power improved the reliability of the remaining relative-power variables. The four variables with the lowest Spearman reliabilities were identified: 2.Delta = .6125, 3.Delta = .6844, 4.Delta = .7196, 2.Beta2 = .7223. To ensure that the method of calculating relative power was consistent within the comparison, new relative-power reliability scores were calculated (note the differences due to rounding error). Adjusted relative-power scores were calculated by dividing the absolute power of a score by the sum of the absolute-powers of the other scores at that region, without the deleted score. Table 4 shows that for the Spearman correlations, 12 of the 16 reliability scores rose when the four unreliable scores were removed. Removal of the unreliable scores improved the reliability of the other scores (two tailed $p < .05$).

Table 4
Changes in Relative Power Reliability After Removal of One
Unreliable Variable

Variable Removed	Variable	Spearman rho	
		With All Variables	Without Deleted Variable
2.Delta	2.Theta	.6634	.6737
	2.Alpha	.7452	.7721
	2.Beta1	.6430	.6936
	2.Delta	.6955	.7158
3.Delta	3.Theta	.7598	.7865
	3.Alpha	.8548	.8972
	3.Beta1	.7331	.7373
	3.Beta2	.8107	.8313
4.Delta	4.Theta	.7551	.7275
	4.Alpha	.8250	.8635
	4.Beta1	.6944	.7249
	4.Beta2	.8011	.8265
2.Beta2	2.Delta	.6228	.6345
	2.Theta	.6634	.6220
	2.Alpha	.7452	.6774
	2.Beta1	.6430	.6307

Note. 2.Delta = region 2 (right frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 4.Beta1 = region 4 (right fr.-temp) beta1 (12.5-17.5 Hz)
 4.Beta2 = region 4 (right fr.-temp) beta2 (17.5-25 Hz)

Changes in Levels of Brain-Wave Activity between Resting and the CPT Task

Changes seen in the level of brain wave activity between resting and the CPT are presented in Table 5. In order for a regional difference to be considered significant, dependent t-tests for Resting - CPT1 had to be significant at the .001 level. This resulted in an overall probability level of .04 ($.001 \times 40 \text{ variables} = .04$). According to this criterion, activity in a number of bands increased significantly between resting and the CPT1. These included frontal delta, fronto-temporal delta, frontal theta, left fronto-temporal beta1, left and right fronto-temporal beta2, left temporal beta2, and left occipital beta2. Left temporal theta, occipital theta, fronto-temporal alpha, and temporal alpha decreased significantly between resting and the CPTs.

Table 5
Differences in Level of EEG Activity

Variable	Resting - CPT1		Resting - CPT2	
	M Difference	p	M Difference	p
1.Delta*	-10.54	<.001	-4.36	.001
2.Delta*	-8.90	<.001	-3.50	.011
3.Delta*	-2.43	<.001	-1.56	.001
4.Delta*	-3.72	<.001	-2.26	.001
5.Delta	- .69	.008	- .44	.064
6.Delta	- .50	.050	- .33	.088
7.Delta	- .04	.845	.13	.436
8.Delta	.16	.249	.13	.312
1.Theta*	-3.08	<.001	-1.29	<.001
2.Theta*	-2.60	<.001	-1.10	<.001
3.Theta	- .46	.007	- .25	.027
4.Theta	- .58	.021	- .21	.213
5.Theta*	1.14	<.001	.95	<.001
6.Theta	1.53	.002	1.51	<.001
7.Theta*	.88	<.001	.81	<.001
8.Theta*	1.27	<.001	1.07	<.001
1.Alpha	.61	.924	.01	.974
2.Alpha	.14	.215	.38	<.001
3.Alpha*	1.77	<.001	1.59	<.001
4.Alpha*	1.77	<.001	1.73	<.001
5.Alpha*	9.26	<.001	6.88	<.001
6.Alpha*	6.81	<.001	5.48	<.001
7.Alpha	4.09	.009	2.67	.103
8.Alpha	4.45	.017	4.75	.009
1.Beta1	- .29	.036	- .55	.002
2.Beta1	- .20	.134	- .33	.008
3.Beta1*	- .64	<.001	- .56	.004
4.Beta1	- .59	.002	- .53	.004
5.Beta1	- .86	<.001	- .29	.247
6.Beta1	- .88	.008	- .06	.826
7.Beta1	- .13	.461	- .12	.447
8.Beta1	- .36	.199	- .07	.743
1.Beta2	-1.64	.007	-3.03	.001
2.Beta2	-1.32	.035	-2.30	.001
3.Beta2*	-4.05	<.001	-3.92	.001
4.Beta2*	-3.11	<.001	-2.82	<.001
5.Beta2*	-4.02	<.001	-2.63	.001
6.Beta2	-3.25	.002	-1.91	.027
7.Beta2*	-1.31	<.001	-1.31	<.001
8.Beta2	-1.67	.004	-1.53	.010

Note. * indicates where CPT1 activity levels was significantly different than resting at the .04 level (.001 x 40 = .04)

Principal Components Analysis

The choice of a PCA. PCA was used to reduce the dimensionality of the 40 EEG variables. It has been demonstrated that there is little difference between the solutions derived from factor analyses and principal components analyses (Fava & Velicer, in press a; Gasser et al., 1983; Schenk et al., 1982; Velicer, 1974; Velicer, 1977; Velicer & Fava, 1987, 1990; Velicer, Peacock, & Jackson, 1982). In the present study (where computational demands were limited and reliable criteria were employed for determining the number of factors/components to extract) there were few practical implications to choosing a principal-components versus a factor analysis (Velicer & Jackson, 1990).

Sample size and component saturation. As a result of the high average loadings, a sample size of 102 was deemed adequate for deriving a reliable PCA solution. Many rules have been suggested for determining the minimum sample size needed for deriving stable and reliable component patterns that would replicate those derived from the population. Using a data simulation study, Guadagnoli and Velicer (1988) demonstrated that component saturation and sample size were the two most important parameters in determining pattern stability. Patterns in which there were more variables per component also tended to be more stable. Neither type-I errors, that is, the incorrect demonstration of a salient loading, nor type-II errors,

that is, the failure to identify a salient loading, occurred with sample sizes greater than 100 and saturation levels greater than or equal to .60.

Table 6
Number of Complex and Unique Absolute-Power (AP) Variables Resulting From Extracting # Components at .60 and .50 Salience Levels

# ^a	Percent of Total Variance ^b	Number of Components Retained at		Number of Complex (C) and Unique (U) Variables at Factor Loadings				Average Component Loading
		.50 ^c	.60 ^d	.50		.60		
				C	U	C	U	
8	67.7	7	6	4	3	0	6	.776
9	69.6	8	7	3	1	1	5	.778
10	60.1	8	6	5	1	0	10	.802
11	62.5	8	7	3	5	2	10	.778
12	70.9	9	8	3	4	0	7	.799
13	59.7	7	6	3	9	0	12	.810
14	64.7	8	7	3	5	1	10	.793
15	62.9	8	7	5	7	0	11	.808
16	62.0	7	7	4	4	0	10	.813
Parallel Analysis = 8				M.A.P. = 16				Scree = 6

^a Number of components extracted

^b Percent of total variance explained after retaining components with > 2 variables loading at .60

^c Number of components retained with > 2 variables loading at .50 or greater

^d Number of components retained with > 2 variables loading at .60 or greater

A number of investigators (Anderson & Rubin, 1956; Velicer & Fava, 1987, 1990; Zwick & Velicer, 1986) have suggested that components with less than three high loadings should not be interpreted. Thus, rather than recalculate the PCA with a smaller component solution, components with less than three variables loading at .60 or greater were discarded. Tables 6, 7, 8, and 9 show

that the average loadings for all of the PCA solutions were quite high, ranging from .737 to .810. This suggests that the sample size ($N = 102$) was sufficient to allow the reliable identification of components.

Table 7

Number of Complex and Unique Log(AP) Variables, Resulting From Extracting # Components at .60 and .50 Salience Levels

# ^a	Percent of Total Variance ^b	Number of Components Retained at		Number of Complex (C) and Unique (U) Variables at Factor Loadings				Average Component Loading
		.50 ^c	.60 ^d	.50		.60		
				C	U	C	U	
6	77.4	6	6	2	0	0	1	.750
Parallel Analysis = 6				M.A.P. = 6				Scree = 6

^a Number of components extracted

^b Percent of total variance explained after retaining components with > 2 variables loading at .60

^c Number of components retained with > 2 variables loading at .50 or greater

^d Number of components retained with > 2 variables loading at .60 or greater

Table 8
 Number of Complex and Unique Relative Power (RP)
 Variables, Resulting From Extracting # Components
 at .60 and .50 Salience Levels

# ^a	Percent of Total Variance ^b	Number of Components Retained at		Number of Complex (C) and Unique (U) Variables at Factor Loadings				Average Component Loading
				.50		.60		
		.50 ^c	.60 ^d	C	U	C	U	
5	65.0	5	4	4	0	1	6	.737
6	62.6	6	4	7	2	1	10	.746
7	64.7	7	5	5	0	0	13	.765
8	69.8	8	6	6	0	0	10	.755
9	71.6	7	7	4	1	0	10	.762
10	68.1	9	7	6	1	0	12	.778

Parallel Analysis = 5

M.A.P. = 10

Scree = 5

^a Number of components extracted

^b Percent of total variance explained after retaining
 components with > 2 variables loading at .60

^c Number of components retained with > 2 variables
 loading at .50 or greater

^d Number of components retained with > 2 variables
 loading at .60 or greater

Table 9
Number of Complex and Unique Log10((RP/(1-RP) Variables,
Resulting From Extracting # Components at .60 and .50
Salience Levels

# ^a	Percent of Total Variance ^b	Number of Components Retained at		Number of Complex (C) and Unique (U) Variables at Factor Loadings				Average Component Loading
		.50 ^c	.60 ^d	.50		.60		
				C	U	C	U	
5	67.6	5	4	9	0	0	5	.761
6	74.0	5	5	6	0	2	6	.752
7	76.2	6	6	7	0	0	6	.760
8	64.3	7	5	9	0	0	11	.764
9	71.0	8	6	7	0	0	10	.767
10	52.5	8	4	12	2	1	17	.758
Parallel Analysis = 5				M.A.P. = 10				Scree = 5

^a Number of components extracted

^b Percent of total variance explained after retaining components with > 2 variables loading at .60

^c Number of components retained with > 2 variables loading at .50 or greater

^d Number of components retained with > 2 variables loading at .60 or greater

Correlation or covariance matrix. Correlation

matrices were used for the PCAs. A PCA may be done on a covariance matrix if the variables are all in the same metric and if the variances do not differ significantly. As can be seen in Appendix B1, however, there are marked differences among variances. For example, the variance for region six, absolute-power alpha waves (6.Alpha) was 2111.23, whereas the variance for region two, absolute-power beta 1 (2.Betal) was only 1.95. Moreover, it theoretically is unlikely that a 2 microvolt change in an alpha variable is equivalent to a 2 microvolt change in theta. Therefore, it was necessary to use standardized scores as provided with the correlation matrix.

Determining the number of components to retain using empirical criteria. Absolute-power variables (AP), relative-power variables (RP), $\log_{10}(\text{AP})$, and $\log_{10}(\text{RP}/1-\text{RP})$ collected during CPT1 were subjected to a PCA using CAX (Velicer, Fava, Zwick, & Harrop, 1988). Components Analysis Extended (CAX) calculates Parallel Analysis (PA) (Allen & Hubbard, 1986) and Minimum Average Partial (MAP) (Velicer, 1976) scores. Scree criteria were calculated by hand. Tables 6, 7, 8, and 9 summarize the results of these analyses. PA, MAP, and scree all agreed on a six-component solution for $\log_{10}(\text{AP})$. In the other three cases, PA and scree indicated somewhat similar results whereas MAP suggested retaining twice the number of components as PA.

Problems associated with underextraction (i.e., loss of important information) or overextraction followed by rotation (i.e., low reliability and uninterpretability) make accurate identification a crucial stage in a PCA (Zwick & Velicer, 1986). Fava and Velicer (in press b) demonstrated that PCA solutions were degraded when overextraction occurred. They found that clear factor patterns with high loadings (i.e., greater than .40) and simple factor patterns (i.e., few mixtures of high and low loadings) appeared to be robust to overextraction. Degradations were most pronounced with small sample sizes and low loadings after three overextractions.

Three decision rules were used to determine the number of components to extract. In the scree test (Cattell, 1966), eigenvalues falling above a line drawn through a plot of the smaller values are retained. The scree test has a tendency to overestimate the number of components to retain with low component saturation or when there are unique or complex variables (Zwick & Velicer, 1986). MAP (Velicer, 1976) identifies all components above the one that consists of only one variable. This unique component is indicated by an increase in the average squared partials after the extraction of that component. Under conditions of low component saturation and few variables per component, MAP tended to underestimate the number of components (Zwick & Velicer, 1986). In PA (Horn, 1965), eigenvalues of a correlation matrix of uncorrelated variables of the same sample size are compared with the obtained eigenvalues. Eigenvalues greater than those from the random matrix are retained. PA was found to be the most accurate of the three methods having a slight tendency towards overestimation (Zwick & Velicer, 1986).

Determining the number of components to retain using theoretical criteria. The range of solutions suggested by the three empirical criteria also was evaluated from a theoretical standpoint. The .60 salience level was chosen instead of a .50 cutoff level. Ten of the 22 possible solutions were selected for further analysis in the

multiple-regression stage. These included the 5-, 7-, 8-, and 10-component solutions for relative power; the 5-, 7-, and 9-component solutions for log-transformed relative power; the 8- and 12-component solutions for absolute power; and the 6-component solution for log-transformed absolute power.

First, the implications of choosing a .60 rather than a .50 cutoff for salience loading are demonstrated in Tables 6, 7, 8, and 9. Any component that did not have at least three variables loading at the cutoff level was dropped. Using a salience cutoff of .50 instead of .60 generally led to the retention of one or two more components. In addition, the number of complex variables, that is, variables that loaded highly on more than one component (Zwick & Velicer, 1986) increased. At the same time, the number of unique variables, that is, those that loaded on only one component with no other variables loading on the same component (Zwick & Velicer, 1986), decreased. Variables with only one other variable loading on the same component also were considered unique. According to the criterion of three or more salient loadings, these components also would be dropped.

The .60 level was selected for use because of replicability concerns due to a relatively small sample size. In addition, it was assumed that there would be redundancy in the information contained in the 40 variables. Thus, dropping unique variables (12.5% to

32.5% of the variables) was not expected to be problematic.

All of the component patterns for the range of solutions suggested by the three rules were plotted out and compared. The plots are presented in Figures 2, 3, 4, 5, 6, 7 and Appendix C. Solutions were selected for the multiple regression if (a) they were theoretically significant, (b) they summarized the other solutions (i.e., contained stable component patterns observed in solutions that were not going to be analyzed), (c) they added to the explained variance, or (d) they provided additional components for analysis. When ambiguous, solutions were included rather than eliminated from further analysis. This resulted in the selection of five solutions from relative power, four from $\log_{10}(RP/1-RP)$, two from absolute power, and one from $\log_{10}(AP)$.

Figure 2. Relative power 5 component extraction

A = Alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.

Waveband in parenthesis i.e., (-A) indicates a complex loading

% indicates percent of total variance this component accounts for. (X) indicates that this component was dropped from analysis because of fewer than 3 variables loading at .60 or greater.

Figure 3. Log10(RP/1-RP) 9 component extraction

A = alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.

% indicates percent of total variance this component accounts for. (X) indicates that this component was dropped from analysis because of fewer than 3 variables loading at .60 or greater.

Figure 4. Absolute Power 8 component extraction

A = alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.

% indicates percent of total variance the component accounts for.

(%) indicates that this component was dropped from analysis because of fewer than 3 variables loading at .60 or greater.

Figure 5. Absolute Power 12 component extraction

A = alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.

% indicates percent of total variance the component accounts for.

(%) indicates that this component was dropped from analysis because of fewer than 3 variables loading at .60 or greater.

Figure 6. Relative Power 7 Component Extraction

A = Alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.

% indicates percent of total variance this component accounts for. (%) indicates that this component was dropped from analysis because of fewer than 3 variables loading at .40 or greater.

Figure 7. Relative Power 8 Component Extraction

A = Alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.

% indicates percent of total variance this component accounts for. (%) indicates that this component was dropped from analysis because of fewer than 3 variables loading at .40 or greater.

Calculating Scores

Component scores were derived by unit weighting (Fava & Velicer, in press a) normalized deviation scores (Fava & Velicer, in press b). A participant's component scores were calculated by summing the person's z-scores on the variables that loaded at .60 or greater. The z-scores were multiplied by 1 or -1, depending on whether the loading of the variable on the component was positive or negative.

Using the conservative criteria employed previously for identifying skewed and kurtotic variables, Table 10 shows that all of the absolute-power component scores were found to be skewed and kurtotic. Many of the other component scores were nearly normally distributed. The most notable exception was the ten-component, relative-power solution (RP10) where four component scores were positively skewed, one was negatively skewed, and one was leptokurtic. Appendix B contains descriptive statistics of the component scores of relative power (RP) and $\log_{10}(\text{RP}/1-\text{RP})$ (LRP) and of absolute-power (AP) and $\log_{10}(\text{AP})$ (LAP) variables.

Table 10
Skewness and Kurtosis of the Component Scores From the
Various Extractions

Extraction (N)	% Kurtotic	(N)	% Skewed	
AP8	100%	(6)	100%	(6)
AP12	100%	(8)	100%	(8)
LAP6	17%	(1)	17%	(1)
RP5	0%	(0)	0%	(0)
RP7	0%	(0)	20%	(1)
RP8	17%	(1)	0%	(0)
RP10	14%	(1)	71%	(5)
LRP5	25%	(1)	0%	(0)
LRP7	17%	(1)	17%	(1)
LRP9	0%	(0)	0%	(0)

Note. AP8 = 8 component extraction Absolute Power
 LAP6 = 6 component extraction Log10(AP)
 RP5 = 5 component extraction Relative Power
 LRP5 = 5 component extraction Log(RP/1-RP)

Component Reliability

Because of the non-normality of the component scores Spearman rho correlations were used to evaluate reliability. Tables 11, 12, 13, and 14 show the six-minute test-retest Spearman correlation coefficients that were calculated for the set of components by correlating component scores from CPT1 with the component scores from CPT2. Twenty five percent of the AP12 components, 17% of the AP8 components, and 33% of the LAP6 components had correlations less than .80 and greater than .70. Twenty-nine percent of the RP10 components, 33% of the RP8 components, 40% of the RP7 components, 50% of the RP5 components, 33% of the LRP9 components, 33% of the LRP7 components, and 50% of the LRP5 components had correlations between .62 and .76. Test-retest correlations of the remaining components were above .80.

Table 11
Six-Minute Test-Retest Reliability of Absolute Power (AP)
Component Scores (CPT1:CPT2) Spearman rho Correlations

Component	rho	Component	rho
12.1	.9387	8.1	.9387
12.2	.7658	8.2	.8115
12.3	.7130	8.3	.7668
12.4	.8622	8.4	.8678
12.5	.9480	8.6	.8622
12.9	.9162		
12.10	.8615		
12.11	.8032		

Note. 8.1 = component 1 of the AP 8 component extraction.

Table 12
Six-Minute Test-Retest Reliability of Log10(AP) Component
Scores (CPT1:CPT2) Spearman rho Correlations

Component	rho
6.1	.9578
6.2	.7750
6.3	.7565
6.4	.8510
6.5	.8589
6.6	.9375

Note. 6.1 = component 1 LAP 6 component extraction.

Table 13
Six-Minute Test-Retest Reliability of Relative Power (RP)
Component Scores (CPT1:CPT2) Spearman rho Correlations

Comp.	rho	Comp.	rho	Comp.	rho	Comp.	rho
10.1	.6703	8.1	.9288	7.1	.6307	5.1	.6498
10.2	.9035	8.2	.6307	7.2	.9274	5.2	.9234
10.3	.8931	8.3	.8721	7.3	.8721	5.3	.9104
10.4	.7559	8.4	.7559	7.4	.7559	5.4	.7559
10.5	.8099	8.5	.8134	7.5	.8099		
10.6	.8069	8.6	.8385				
10.9	.9097						

Note. 5.1 = component 1 of the RP 5 component extraction.

Table 14

Six-Minute Test-Retest Reliability of Log10(RP/1-RP)
Component Scores (CPT1:CPT2) Spearman rho Correlations

Comp.	rho	Comp.	rho	Comp.	rho
9.1	.6226	7.1	.6232	5.1	.6290
9.2	.9142	7.2	.9118	5.2	.9315
9.3	.8632	7.3	.8668	5.3	.8978
9.4	.7498	7.4	.7498	5.4	.7498
9.6	.8842	7.6	.8825		
9.7	.8114	7.7	.8114		

Note. 9.1 = component 1 of the LRP 9 component extraction.

Six-Minute Test-Retest Reliability of Performance Measures

Table 15 shows test-retest reliability scores for the various error indexes obtained on the 102 participants by correlating performance scores from CPT1 with performance scores from CPT2. Error indexes were normally distributed. Pearson product-moment correlation coefficients (r^{tt}) were used to calculate reliability. The reliability of the Omission Error Index ($r^{tt} = .48$), Detection Index ($r^{tt} = .48$), and Error Index ($r^{tt} = .49$) were all poor but roughly comparable.

Table 15
Descriptive Statistics of Performance Indexes and Change
in Omission Errors
During CPT1

Index	M	<u>SD</u>	Kurtosis	Skewness	Minimum	Maximum
Io	.080	.067	-.138	.691	.00	.27
Co	.012	.009	4.023	1.686	.00	.05
P(D)	.908	.067	.191	-.779	.71	1.00
Error	.103	.068	.546	.828	.00	.31
<hr/> CPT1-CPT2						
Io	-.067	.096	-.211	-.425	-.308	.111

Note. Io = omission errors/omission opportunities;
Co = commission errors/commission opportunities;
 $P(D) = 1 - Io - Co$; Error Index = $Io + 2Co$

Multiple Regression on Level of Performance

None of the multiple-regressions equation predicted omission errors to any significant degree. The fourth component from the relative-power, five-component solution (RP5.4) and the fourth component from the $\log_{10}(RP/1-RP)$, nine-component solution, however, were significantly correlated with omission errors.

SPSSX (SPSS, Inc., 1986) was used to perform a series of standard multiple regressions. These were executed using component scores as the predictors and percent omission errors in CPT1 as the criterion. Although all of the performance measures demonstrated equally poor reliability, omission errors have been used in many previous CPT studies. Table 16 demonstrates that the multiple regression equations explained between 3% and 9% of the variance in omission errors; none of these regressions were significant. Tables 17, 18, and 19 show

that two of the components, RP5.4 and LRP9.4 were correlated with performance at the .05 level.

Table 16
Multiple Regression Results

Extraction	Omission Errors CPT1		Error Change CPT1-CPT2		Significant Components	
	R ²	p	#	p	R ²	p
AP8	.04	.64			.08	.21
AP12	.08	.42			.13	.10
LAP6	.03	.83			.06	.42
RP5	.06	.20	RP5.4	.036	.03	.52
RP7	.07	.23			.05	.38
RP8	.09	.16			.09	.17
RP10	.09	.27			.05	.69
LRP5	.05	.25			.03	.61
LRP7	.07	.33			.07	.29
LRP9	.06	.39	LRP9.4	.046	.07	.29

Note. AP8.6 = component 6 of the AP 8 component extraction.
RP5.4 = component 4 of the RP 5 component extraction.

Table 17
Standard Multiple Regression of Component Scores From Five Component Relative Power Extraction on Omission Errors in CPT1

Comp.	% Omissions (DV)			Beta	Semi Partial Correlation	
	5.4	5.3	5.2		p	p
5.4	-.166			-.218891	-.209343	.0361
5.3	.073	-.117		.139402	.125105	.2072
5.2	-.061	-.100	.293	-.093938	-.078993	.4247
5.1	-.085	-.193	-.117	.409	-.072856	-.063654
Multiple R		.24167		F (4,97) =		1.50418
R squared		.05841		p =		.2070
Adjusted R squared		.01958				

Table 18

Correlations of CPT1 Component Scores From Nine Component
Log10(RP/1-RP) Extraction Multiple Regression on CPT1
Omission Errors

	9.1	9.2	9.3	9.4	9.6
9.2	.157				
9.3	-.087	.181			
9.4	-.073	-.098	.295		
9.6	-.131	.663	.309	-.169	
9.7	-.317	-.239	.433	.462	-.137

Table 19

Standard Multiple Regression of Component Scores From Nine
Component Log10(RP/1-RP) Extraction on Omission Errors in
CPT1

Component	Beta	r	Semi Partial Correlation	F	p
9.1	-.059928	-.112609	-.053058	.285	.5945
9.2	-.066364	-.044300	-.046367	.218	.6417
9.3	.011219	.023803	.008956	.008	.9284
9.4	-.233260	-.157946	-.200460	4.072	.0464
9.6	.066323	.051569	.043757	.194	.6606
9.7	.156434	.079212	.116871	1.384	.2423
Multiple R		.25022	F (6,95) =		1.05753
R squared		.06261	p =		.3936
Adjusted R squared		.00341			

Outliers on the criterion were identified using studentized residuals. Outliers on the predictors were identified by examining the Mahalanobis distances ($p < .001$). None of these outliers appeared to be influential however; Cook's distances were all below 1, thus they were left in the analyses (Stevens, 1986).

Multiple Regression on Change in Level of Performance (Vigilance Decrement)

Table 16 shows that none of the multiple regressions predicted change (CPT1-CPT2) in omission errors (i.e.,

vigilance decrement) to any significant degree. Tables 21, 23, 25, and 27 show that the sixth component from the absolute-power, eight-component solution (AP8.6); the second and fourth components from the absolute-power, 12-component solution (AP12.2 and AP12.4); the third component from the relative-power, seven-component solution (RP7.3), and the third component from the relative-power eight-component solution (RP8.3) were significantly correlated with the vigilance decrement at the .05 level.

Table 20

Correlations of Component Scores From Eight Component Absolute Power (AP) Extraction Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	8.1	8.2	8.3	8.4	8.5
8.2	.003				
8.3	.300	-.087			
8.4	.264	.300	-.097		
8.5	.580	-.143	.158	.275	
8.6	-.007	.532	.054	.308	-.065

Table 21

Standard Multiple Regression of Component Scores From Eight Component Absolute Power (AP) Extraction on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
8.6	-.251398	-.167384	-.205744	4.384	.0389
8.5	.098389	.044091	.076879	.612	.4359
8.4	-.122960	-.129200	-.105622	1.155	.2851
8.3	.129495	.110883	.119444	1.478	.2272
8.2	.227288	.031135	.184461	3.524	.0636
8.1	-.042855	.023026	-.032963	.113	.7380
Multiple R		.28767	F (6,95) =		1.42847
R squared		.08275	p =		.2118
Adjusted R squared		.02482			

Table 22

Correlations of Component Scores From Twelve Component Absolute Power (AP) Extraction Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	12.1	12.2	12.3	12.4	12.5	12.9	12.10
12.2	-.044						
12.3	.279	-.082					
12.4	-.007	.440	.009				
12.5	.603	-.151	.244	-.096			
12.9	.384	.192	.123	.010	.302		
12.10	.061	.335	-.117	.439	-.065	.288	
12.11	.293	.036	.804	.102	.179	.239	-.071

Table 23

Standard Multiple Regression of Component Scores From Twelve Component Absolute Power (AP) Extraction on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
12.1	-.106787	.023026	-.080324	.690	.4084
12.2	.267685	.126504	.228138	5.563	.0204
12.3	.262349	.136678	.149665	2.394	.1252
12.4	-.239158	-.167384	-.193938	4.020	.0479
12.5	.115466	.109614	.088465	.837	.3628
12.9	.115966	.139497	.095256	.970	.3273
12.10	-.055000	-.071069	-.045141	.218	.6418
12.11	-.149925	.067460	-.083533	.746	.3900
Multiple R		.36045	F (8,93) =		1.73586
R squared		.12992	p =		.1003
Adjusted R squared		.05508			

Table 24

Correlations of Component Scores From Seven Component Relative Power (RP) Extraction Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	7.1	7.2	7.3	7.4
7.2	.263			
7.3	-.095	.018		
7.4	-.101	-.247	.015	
7.5	.373	-.217	-.064	.325

Table 25

Standard Multiple Regression of Component Scores From Seven Component Relative Power (RP) Extraction on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
7.1	.091179	.011793	.076472	.593	.4431
7.2	-.128444	-.078151	-.115244	1.347	.2487
7.3	.200297	.194023	.199125	4.021	.0477
7.4	-.023729	-.023523	-.021582	.047	.8284
7.5	-.077848	-.036515	-.063527	.409	.5239
Multiple R		.23103	F (5,96) =		1.08261
R squared		.05338	p =		.3750
Adjusted R squared		.00407			

Table 26

Correlations of Component Scores From Eight Component Relative Power Extraction Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	8.1	8.2	8.3	8.4	8.5
8.2	.297				
8.3	-.077	-.095			
8.4	-.249	-.101	.015		
8.5	-.205	.332	-.055	.310	
8.6	-.474	-.272	.360	.365	.121

Table 27

Standard Multiple Regression of Component Scores From Eight Component Relative Power Extraction on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
8.1	-.228117	-.106913	-.188845	3.722	.0567
8.2	.080715	.011793	.068247	.486	.4874
8.3	.258194	.194023	.237053	5.865	.0173
8.4	.036876	-.023523	.032435	.110	.7411
8.5	-.100998	-.057228	-.084996	.754	.3874
8.6	-.222831	-.042566	-.171521	3.071	.0829
Multiple R		.29972	F (6,95) =		1.56275
R squared		.08983	p =		.1665
Adjusted R squared		.03235			

A series of standard multiple regressions were performed using absolute change in component scores (CPT1-CPT2) as the predictors and absolute change in percent omission errors (CPT1-CPT2) as the criterion. Appendix B contains the descriptive statistics of the absolute-power and relative-power component change scores and the descriptive statistics of the omission-error change scores. The multiple regression formulas explained between 3% and 13% of the variance in change of omission errors. Table 17 shows that none of these regressions were significant. Tables 20, 21, 22, 23, 24, 25, 26, and 27 show that five of the components, AP8.6, AP12.2, AP12.4, RP7.3, and RP8.3 were correlated with change in performance at the .05 level. Once again, none of the outliers appeared to be influential (i.e., Cook's D below 1).

Post-hoc Multiple Regressions

As a post hoc analysis, four components were selected for further investigation. These included absolute-power frontal beta (AP12.2); absolute-power right fronto-temporal and right temporal-occipital beta (AP12.4); relative-power frontal and right fronto-temporal theta (RP5.4); and relative-power occipital theta, right occipital delta, and right temporal theta (RP8.3). These were selected because the planned analyses had shown them to be correlated with level of omission errors in CPT1 or change in omission errors (CPT1-CPT2). LRP9.4, AP8.6, and

RP7.3 were not used because they were identical to other components.

Two multiple regressions were conducted with level of omission errors in CPT2 as the criterion. In the first multiple regression equation, component scores of AP12.4 and AP12.2 at CPT1 and CPT2 were used as predictors. In the second multiple regression equation, component scores of RP5.4 and RP8.3 at CPT1 and CPT2 were used as predictors.

Table 28 shows that R^2 for the absolute-power multiple regression was .09. Although this regression was not significant at conventional alpha levels ($p = .06$), all of the variables significantly correlated with the level of CPT2 omission errors ($p < .05$).

Table 28
Standard Multiple Regression of CPT1 (A) and CPT2 (B)
Component Scores From Twelve Component Absolute Power
Extraction on Omission Errors in CPT2

% Omissions		Semi Partial					
Comp.	(DV)	A12.2	A12.4	B12.2	Beta	Correlation	p
A12.2	.059				-.378476	-.191660	.0509
A12.4	.097	.334			.500171	.237399	.0161
B12.2	.140	.833	.263		.520374	.253655	.0103
B12.4	.022	.336	.851	.403	-.486322	-.224211	.0228
Multiple R		.29761		F (4,97) =		2.35658	
R squared		.08857		p =		.0589	
Adjusted R squared		.05099					

Table 29 shows that R^2 for the relative-power multiple regression was .06. This regression was not

significant ($p = .42$). Only RP5.4 at CPT2 was correlated with the level of CPT2 omission errors ($p < .05$).

Table 29

Standard Multiple Regression of CPT1 (A) and CPT2 (B)
Component Scores From Five and Eight Component Relative
Power Extraction on Omission Errors in CPT2

% Omissions						Semi Partial	
Comp.	(DV)	A5.4	A8.3	B5.4	Beta	Correlation	p
A5.4	-.079				-.048280	-.031068	.7546
A8.3	-.001	.321			-.308644	-.153099	.1257
B5.4	-.069	.763	.364		-.031625	-.020049	.8401
B8.3	.105	.237	.858	.286	.390430	.199666	.0467
Multiple R		.21718		F (4,97) =		1.20041	
R squared		.04717		p =		.3156	
Adjusted R squared		.00787					

Discussion

In this section, the ten predictions regarding the transformations of scores and the psychometric properties of variables, component scores, and performance indexes are discussed. The predictions regarding changes in EEG variables between Resting and CPT1 subsequently are considered. The outcome of the set of planned multiple regression equations is then described. Finally, the results of the post-hoc multiple regression equation are examined.

Transformation of Scores

The first prediction was that the $\log_{10}$ transformation would normalize absolute power and that the $\log_{10}(x/1-x)$ transformation would normalize relative power. Findings for EEG collected during an auditory CPT were consistent with the literature on resting EEG.

Log10(AP) produced the most normal distribution of absolute-power scores and log10(RP/1-RP) produced the most normal distribution of relative-power scores (see Table 1).

These transformations, however, were not perfect. For example, after transformation, for absolute-power variables, 12.5% of the log10(AP) variables remained leptokurtic and 17.5% of the variables remained skewed. For relative-power variables, 22.5% of the log10(RP/1-RP) variables were leptokurtic and 17.5% of these variables were skewed.

In contrast to Pollock et al. (1990) who reported that absolute theta amplitude ($\text{power}^{1/2}$) was not normalized with the log transformation, log10(AP) theta at six of eight channels in the present study was normally distributed. There was no evidence of excessive amounts of theta non-normality using their more stringent criteria for skewness and kurtosis, under either resting or CPT conditions. Pollock et al. (1990) however, did record EEG from a number of locations that were not monitored in the present study. Oken and Chiappa (1988) reported that relative power had fewer skewed results than absolute power. In the present study, this was supported for non-transformed but not for log-transformed scores. Finally, although some authors have used the natural log instead of log10 to normalize scores, this does not present a problem for the present study because logarithms are constant

multiples of each other (Tukey, 1977), therefore, results of the two transformations would be equivalent.

Absolute-Power and Relative-Power Reliability

The second prediction was that absolute-power variables would be more reliable than relative-power variables. This prediction was supported. Among young adults, short term (i.e., six-minute) test-retest reliability was significantly greater for absolute power than for relative power, for EEG collected during a auditory continuous performance test. This was true regardless of whether transformed or non-transformed values were analyzed or whether the non-parametric Spearman rank-order correlation or the parametric Pearson product-moment correlation was used to assess reliability.

Pollock et al. (1991) reported that delta amplitude reliability was low. Gasser et al. (1985) found that this was true for absolute-power delta and even more so for relative-power delta. Low reliabilities among anterior but not posterior delta scores were found in the present study. Reliabilities of right frontal theta, alpha, beta1, and beta2 also tended to be low, particularly for relative-power measures.

The double cross-validation procedure demonstrated that the relationship of relative-power variables across groups was not more consistent than the relationship of absolute-power variables across groups. One of the cross-validations showed that absolute-power variables were more

consistent than relative-power variables, the other cross-validation showed no difference.

It was hypothesized that absolute-power reliability would be greater than relative-power reliability because relative-power reliability would be limited by unreliability among the constituent dependent scores. In other words, the least reliable score would reduce the reliabilities of the other scores that use that variable in their calculations of relative power. Removal of the least reliable variables significantly improved short-term, test-retest reliability. In terms of enhancing reliability, however, removal of one unreliable score was not particularly meaningful. For example, the largest change only accounted for an additional one-half of one percent of error variance in the scores.

PCA and Component Scores

The third prediction was that component scores derived from PCAs on absolute- and relative-power variables would be reliable with short-term test-retest correlations greater than .80 (i.e., error variance < 20%). This prediction was supported for 77% of the non-transformed absolute-power components, 66% of the $\log_{10}(\text{AP})$ components, 64% of the non-transformed relative-power components, and 63% of the $\log_{10}(\text{RP}/1\text{-RP})$ components (see Tables 11, 12, 13, and 14).

Components derived in the present study are not directly comparable to those reported in other studies.

For example, in the present study a PCA was performed on EEG collected during a continuous performance test whereas in other studies (e.g., Ott et al., 1982; Schenk et al., 1982; Gasser et al., 1983) PCAs were performed on EEG data collected during eyes-closed resting conditions. Bente (1979) conducted one PCA on EEG data collected during resting and another on EEG data collected during a visual tracking task. In addition, these other PCAs were conducted on EEG data collected from one or two channels in contrast to the present eight-channel study. Bente and Ott et al. collected EEG from occipital leads. Schenk et al. collected EEG from bipolar right occipital and right parietal leads (C4-P4, P4-O2). Finally, Bente, Schenk et al., and Ott et al. derived different wavebands than the ones used in the present study. Gasser et al. defined their bands similarly to the present study with the exception that they divided alpha into two bands, (i.e., 7.5 to 9.5 Hz and 9.5 to 12.5 Hz).

The other PCA studies also suffered from methodological shortcomings, particularly, small sample sizes. Bente (1979), Schenk et al. (1982), Ott et al. (1982), and Gasser et al. (1983) used sample sizes of 12, 41, 60, and 31 respectively. Guadagnoli and Velicer (1988) demonstrated that PCAs derived on small samples were unlikely to replicate the population pattern adequately. Gasser et al. (1983) chose not to rotate their PCA solution because it eliminated the general

topographic factor. Given a hypothesis of task-associated, regional differences in brain activity, it is unclear why a general topographic factor would be necessary. In any event, this procedure resulted in a two-factor solution, not a three-factor solution as they suggested. The average loading on factor 1 was 0.87, on factor 2 it was 0.31, and on factor 3 it was 0.17. Factor 1 was a general topographic factor as they suggested. Factor 2 contained left- and right-sided positive occipital variables plus negative frontal delta and beta variables. Factor 3 only comprised one variable that loaded above 0.40.

Bente's (1979) fifth factor was somewhat comparable to RP5.3. The first factor that Ott et al. (1982) described contained elements of RP5.3, RP10.9, and RP8.3. The second factor that Schenk et al. (1982) described seems similar to the first factor of the absolute-power solution (i.e., AP12.1).

PCA Solution

Five component pattern solutions were hypothesized prior to conducting the PCA. The first possibility was that a two-component solution that divided the brain either sagittally (i.e., into left and right hemispheres) or coronally (i.e., into anterior and posterior sections) would emerge. The second possibility combined these two options into a four-component solution (i.e., left anterior, right anterior, left posterior, and right

posterior). The third possibility was a four-component solution that separated the brain by region (i.e., frontal, fronto-temporal, temporal, and temporal-occipital). The fourth possibility was a five-component solution with each band (i.e., delta, theta, alpha, beta1, and beta2) emerging as a separate component. The fifth possibility was that the component would emerge as a combination of the other patterns. In fact, the observed patterns appeared consistent with the fifth possibility in that combinations of region-, hemisphere-, and band-related components emerged. More specifically, delta- and theta-wave bands tended to emerge together. Similarly, beta1- and beta2-activity was highly correlated. Anterior and posterior components were found. In the fronto-temporal and temporal regions, beta sometimes split into left- and right-hemisphere components.

A theoretically interesting pattern discussed here as an illustration was that of the 12-component, absolute-power solution. Four components from this solution were dropped from analysis because fewer than three variables loaded on those components at .60 or greater. After removing those variables, the remaining eight components accounted for 70.9% of the total variance. The multiple-regression equation that used the eight remaining components for predicting CPT1 - CPT2 omission-error changes accounted for the greatest amount of variance (13%) of any of the multiple-regression equations. Figure

8 displays the 12-component, varimax-rotation, absolute-power solution without the four omitted components.

Appendix D displays the varimax and promax rotations of the 12-component, absolute-power extraction.

<div> <div>+</div> <div>+</div> <div>+</div> <div>A A</div> <div>TD D T</div> <div>+</div> <div>T T</div> </div>	<div> <div>B2</div> <div>+</div> <div>+</div> <div>B1 B2</div> <div>+</div> <div>+</div> </div>	<div> <div>D D</div> <div>T T</div> <div>+</div> <div>+</div> <div>+</div> <div>+</div> </div>	<div> <div>+</div> <div>+</div> <div>+</div> <div>B1 B2</div> <div>+</div> <div>+</div> <div>B1 B2</div> </div>	<div> <div>+</div> <div>+</div> <div>+</div> <div>+</div> <div>+</div> <div>+</div> </div>	<div> <div>A A</div> <div>A A</div> <div>+</div> <div>+</div> <div>+</div> <div>+</div> </div>	<div> <div>+</div> <div>+</div> <div>+</div> <div>B1 B2</div> <div>+</div> <div>+</div> <div>B1 B2</div> </div>	<div> <div>+</div> <div>+</div> <div>+</div> <div>D D</div> <div>T T</div> <div>+</div> <div>+</div> </div>
12.1	12.2	12.3	12.4	12.5	12.9	12.10	12.11
15.4%	8.1%	10.6%	8.3%	7.9%	6.0%	8.1%	6.5%

Figure 8. Absolute Power 12-component extraction.

A = alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.
 12.1 = component 1 of the 12-component extraction. % = the amount of total variance accounted for by this component. Four components were dropped because of fewer than 3 variables loading at .60 or greater.

When these components are considered in the context of the previously cited theoretical research relating EEG activity to vigilance, several hypotheses can be advanced. For example, component 12.1 may be a posterior tonic arousal component reflecting the individual's overall level of alertness. Component 12.2, which is positively correlated with omission errors, may reflect activity in the frontal lobes. This could involve planning activities unrelated to the CPT task. Components 12.3 and 12.11, which are both anterior phasic arousal components, may reflect the amount of resources directed to performing the

task. As the task is mastered individuals may decrease their phasic arousal yet still perform well. Supporting this hypothesis, these components were moderately positively correlated with omission errors. Component 12.4, which was negatively correlated with omission errors, may reflect activity in the vigilance center of the right hemisphere. Components 12.5 and 12.9 which were positively correlated with omission errors, may reflect a level of inattention and underutilized processing resources. Component 12.10 may reflect processing in the language and phonemic decoding center. As such it is unlikely that brain-wave activity in these channels would be influenced by memory operations in deep structures such as the hippocampus and amygdala. Because the language area is being constantly stimulated throughout the language task, activity in this area would be expected to remain constant throughout the task. Again, supporting this hypothesis, the component was uncorrelated with omission errors.

CPT Performance Measures

The fourth prediction was that the detection index would be the most reliable measure of CPT performance. This prediction was not supported among either the six-minute or one week, test-retest, Pearson product-moment correlations. Reliabilities were low at one week (.33 to .37) and at six minutes (.48 to .49). The omission error index, which had been used in other research studies, had

slightly higher reliability than the others (i.e., .37 at one week and .48 at six-minutes) and was chosen as our criterion measure.

These low reliabilities are perhaps not unexpected in view of the fact that vigilance, as measured by these performance indexes, may be an unstable trait. Level of attention conceivably could vary from week to week (one week correlations) or change over time, in different ways, across subjects (six-minute correlations). Figures 9, 10, and 11 and Table 15 demonstrate that these scores were also not normally distributed and had restricted ranges.

Figure 10. Percent omission errors CPT2

Figure 11. Change in percent omission errors CPT1-CPT2

Because attention may be variable, one possible way to evaluate these reliability estimations is to assess

reliability over shorter durations, for example, successive, one-minute periods. Another possibility is to correlate reliability during odd numbered epochs (i.e., one minute, three minute, five minute) with even numbered epochs (i.e., two minute, four minute, six minute). This would correct for interindividual differences in vigilance decrement. Of course, this would provide an indication of the measure's internal consistency rather than its stability.

The lack of reliability, for whatever reason, reduces the power of any statistical analysis in which it is used. Reliability is a necessary element of behavioral tasks that are performed during physiological monitoring (Gur, Erwin, & Gur, 1992). It is possible that other measures such as reaction time would be more reliable, that the test could be made more difficult in order to eliminate the ceiling effect and spread the range of scores, or that reliabilities would be greater if used with a less homogeneous sample (i.e., one that included both control and head injured individuals).

Changes in Levels of EEG Activity

The fifth and sixth predictions were that the absolute power of beta activity during CPT1 in channels 1, 2, 3, 4, 5 and 6 would increase over resting levels and that the absolute power of alpha and theta activity would decrease between Resting and CPT. These predictions were supported for channels 3 of beta1; channels 3, 4, 5, and

7 of beta2; posterior theta; and channels 3, 4, 5, and 6 of alpha. The left-sided beta findings are suggestive of changes that might be the result of activity in language areas of the brain. This indicates that EEG is sensitive to these types of changes in brain activity. One unexpected finding was that frontal theta also increased between Resting and CPT1.

One possible explanation for this unexpected finding in frontal theta is that EEG activity below the artifact level, which may have been due to eye movement, was neither recorded separately nor removed. Eye movement theoretically could contaminate slow frequency bands such as delta, theta, and the lower ranges of alpha. For example, rhythmic muscle contractions could generate voltage changes that, if received at the frontal leads, would be recorded as brain-wave activity in these slow-frequency wave bands.

Randolph and Miller (1988) reported increases in delta at T3 and T4 referenced to Cz. In the present study, the anterior channels, which used the T3 and T4 leads (channels 3 and 4), showed an increase in delta whereas the posterior channels (5 and 6) did not. It is possible that Randolph and Miller's report of increased delta at T3 and T4 may have been the result of contamination due to eye movement.

Finally, a variety of parameters may change between Resting and CPT1 such as: anxiety, motivation,

muscle tension, alertness, as well as level of attention and vigilance. These parameters need not all move in the same direction, at the same time. EEG may reflect some or all of these factors.

Predicting Level of Performance

The seventh prediction was that component scores from components consisting of absolute-power beta from channels 1, 2, 3, 4, 5, and 6 would be related to level of performance during CPT1. This prediction was not supported. None of the multiple regressions were significant; none predicted performance. Unreliability in the dependent variable results in an increase in the standard error of estimate, thus weakening tests of statistical significance (Pedhazur, 1982). This could be one explanation for the inability of the multiple-regression equations to predict the unreliable ($r_{tt} = .48$) omission error score. A component consisting of channels 1, 2, and 4 relative-power theta, however, was negatively correlated with the level of omission errors during CPT1.

Predicting Changes in Level of Performance

The eighth prediction was that CPT1 to CPT2 changes in component scores from components comprising absolute-power beta from channels 2 and 4 would be negatively correlated with CPT1 to CPT2 performance change (i.e., as the number of omission errors increased, beta would decrease). The ninth prediction was that changes in component scores from components comprising absolute-power

beta from channels 7 and 8 would be negatively correlated with performance change. The tenth prediction was that changes in component scores from components comprising absolute-power theta and alpha from channels 7 and 8 would be positively correlated with performance change. None of these predictions were supported. None of the multiple regressions were significant; none predicted performance. As noted above, unreliability in the dependent variable results in an increase in the standard error of estimate, thus weakening tests of statistical significance (Pedhazur, 1982). Because difference scores are more unreliable than either score alone (Willis & Goodwin, 1987), this could be one explanation for the inability of the multiple-regression equations to predict the omission error change score. Changes in certain components, however, were correlated with changes in omission errors. These included in : (a) negative correlations with channels 4 and 6 absolute-power β_1 and β_2 , (b) positive correlations with channels 1 and 2 absolute-power β_2 , (c) positive correlation with channel 2 absolute-power β_1 , (d) positive correlations with channels 6, 7, and 8 relative-power theta, and (e) positive correlation with channel 8 relative-power delta.

Because none of the multiple regressions was significant, it was not possible to demonstrate that components derived from absolute-power variables were superior to relative-power variables, transformed

absolute-power, or transformed relative-power variables in predicting performance. The absolute-power, 12- component extraction (AP12) multiple regression, however, explained more of the variance ($R^2 = .13$) and came the closest to predicting performance ($p = .10$).

Post-hoc Analyses

A post hoc analysis was conducted on the data in order to derive hypotheses for future research studies. In the first step, component correlations were evaluated for every component ($N = 57$).

The anterior relative-power theta component (RP5.4 or LRP9.4) was negatively correlated with omission errors. The anterior absolute-power beta component (AP12.2) was positively correlated with changes in omission errors. The right sided absolute-power beta component (AP8.6 or AP12.4) was negatively correlated with changes in omission errors. The posterior relative-power theta component (RP8.3 or RP7.3) was positively correlated with changes in omission errors. The posterior relative-power theta component was expected from a review of EEG literature (e.g., Davies & Parasuraman, 1982; Parasuraman, 1984). The right-sided absolute-power beta component could be explained if the electrodes recorded right parietal and temporoparietal activity suggested from PET studies (e.g., Buchsbaum et al., 1990).

There are multiple possible explanations for the failure of any absolute-power component to explain level

of performance. For example, there was a large interindividual variability of absolute-power measures. If one person's baseline EEG activity were consistently greater than another's, high test-retest reliabilities and low correlations of level of absolute-power EEG activity and performance would be expected. Relative-power corrects for scale and, therefore should be more predictive of level of performance. Difference scores also correct, to some extent for scale, although it does not seem likely that one person's change from 200 microvolts to 198 microvolts would be equivalent to another person's change from 4 microvolts to 2 microvolts.

Traditional vigilance tasks are often longer in duration which should lead to a greater vigilance decrement. It may be that the brief nature of the present task concealed an effect which might have emerged had the task been longer in duration. Similarly, the task itself may not have been sufficiently difficult for some people and hence, they were able to perform well without exerting a great deal of attention. The limited range of error scores not only suggests that this is a viable hypothesis, but also, in effect, reduces the statistical power of the analyses. Many factors could contribute to changes in levels of performance including: attention level, attention capability, arousal, memory, effort. It is likely that no individual component or set of components reflect this complex combination of factors in any

straightforward manner. It is also conceivable that the electrodes were not at the correct locations (i.e., not over the parietal lobe) or that the scalp EEG is too crude an instrument to detect subtle attentional changes manifesting themselves below the surface of the cerebral cortex. Additionally, not all available quantitative EEG measures (i.e., coherence and assymetry), were included in the analysis. It is possible that analyses using these measures may have been more productive.

Another possibility that might have contributed to being unable to predict performance was unreliability in the measures. Not only were the performance measures unreliable, but it has been shown that difference scores in neuropsychological research are less reliable than either variable alone (Willis & Goodwin, 1987). As an alternative, Willis and Goodwin (1987) suggested using an analysis of covariance with one element of the difference score used as the dependent variable and the other used as a covariate.

This technique was not directly applicable because in the present study independent variables were continuous rather than categorical. However, extending the technique, if absolute-power variables do not explain performance because of disparities in scale between individuals and if difference scores reduce the reliability and, therefore, the power of statistical analyses, it seems reasonable to expect that a multiple

regression which used both CPT1 and CPT2 EEG component scores could predict level of performance in CPT2.

This was the rationale for the post-hoc multiple regression reported in the Results section. Although neither of the multiple regressions reached significance, the near-significant absolute-power result suggested the validity of using this multiple regression approach, and the need of a follow-up examination of the absolute-power solution. In order to validate the absolute-power multiple regression, the formula could be applied to an independent sample to determine the extent to which it could predict performance during CPT2.

Summary

For EEG collected on young adults during an auditory CPT, $\log_{10}(\text{AP})$ produced the most normal distribution of absolute power scores and $\log_{10}(\text{RP}/1-\text{RP})$ produced the most normal distribution of relative power scores. Absolute power was shown to have greater short-term reliability than relative power.

Left-sided beta2 and right-frontal and right-fronto-temporal beta2 increased between Resting and CPT1. This finding is consistent with the literature and suggestive that EEG is, in fact, sensitive to the type of brain-activity changes that result when moving from a resting condition to an attentive condition. Alpha activity declined in fronto-temporal and temporal regions bilaterally. Frontal, temporal, temporal-occipital theta

and anterior delta showed an unexpected increase in activity between Resting and CPT1. As expected, left-sided beta2; right-sided, fronto-temporal beta2, and left-sided, fronto-temporal beta1 increased between resting and CPT1.

The majority of components derived from PCAs on these scores had short-term test-retest correlations greater than .80. A component comprising frontal relative-power theta was negatively correlated with omission errors during CPT1. CPT1 - CPT2 changes in components comprising right-sided, fronto-temporal and temporal absolute-power beta were negatively correlated with CPT1 - CPT2 changes in omission errors. CPT1 - CPT2 changes in components comprising frontal absolute-power beta and posterior relative-power theta were positively correlated with CPT1 - CPT2 changes in omission errors. However, none of the multiple regression equations based upon CPT1 component scores predicted level of omission errors in CPT1. None of the multiple regression equations based upon CPT1 - CPT2 component change scores predicted vigilance decrement. In post hoc analysis, none of the multiple regression equations that included component scores from CPT1 and CPT2 as independent variables significantly predicted level of omission errors in CPT2. Frontal and right-sided absolute-power beta components (12.2 and 12.4) appeared, however to be promising, and seem to warrant a follow-up study for cross validation. The potential

importance of this finding is that a physiological measure nearly predicted a behavioral measure of attention. The absolute-power, 12-component PCA solution, despite lacking empirical validation of its predictability, appeared to be superior to the other solutions from both a theoretical and empirical perspective. Thus, it is offered as the most promising arrangement of EEG variables during the auditory CPT.

Appendix A

Handedness Inventory

EEG Study

Adapted from the Edinburgh Inventory

Have you ever had any tendency toward left-handedness?

Yes

No

Is anyone in your family left-handed (i.e., Parents, siblings)?

Yes

No

If you are left-handed, do you write with an inverted hand posture?

Yes

No

Please indicate your preference in the use of hands in the following activities by putting a + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++. If in any case you are really indifferent, put + in both columns.

Please try to answer all the questions and only leave a blank if you have no experience at all of the objects or task.

	Right	Left
Writing.....		
Drawing.....		
Throwing.....		
Scissors.....		
Comb.....		
Toothbrush.....		
Spoon.....		
Hammer.....		
Opening a book (lid).....		
Striking a match (match).....		
Dealing cards.....		
Which foot do you prefer to kick with?.....		
Which eye would you use to look through a telescope?.....		

Appendix B

Table B1
Descriptive Statistics of Absolute Power EEG Collected
During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	20.94	25.32	8.21	2.74
2.Delta	19.44	22.52	10.91	3.08
3.Delta	7.98	6.52	23.58	4.14
4.Delta	9.55	10.06	18.37	3.83
5.Delta	8.24	5.34	12.22	2.92
6.Delta	7.67	6.11	14.95	3.26
7.Delta	4.84	4.88	23.58	4.11
8.Delta	4.18	2.64	1.95	1.43
1.Theta	7.72	8.19	11.73	3.05
2.Theta	6.59	6.05	9.67	2.81
3.Theta	4.00	2.38	6.69	2.20
4.Theta	4.16	2.90	13.09	3.06
5.Theta	6.99	6.19	11.98	3.12
6.Theta	7.18	9.72	31.49	4.99
7.Theta	5.24	4.62	7.28	2.43
8.Theta	4.82	4.15	10.40	2.71
1.Alpha	3.88	3.43	16.13	3.50
2.Alpha	3.15	2.30	8.18	2.54
3.Alpha	4.82	3.40	5.13	2.02
4.Alpha	5.06	3.79	3.74	1.83
5.Alpha	26.07	28.90	6.31	2.23
6.Alpha	31.46	45.95	9.80	3.07
7.Alpha	25.81	41.52	46.37	5.94
8.Alpha	25.02	28.84	13.78	3.06
1.Betal	1.68	1.83	28.70	4.67
2.Betal	1.35	1.40	55.24	6.58
3.Betal	2.80	2.07	3.71	1.80
4.Betal	2.55	2.48	33.74	5.06
5.Betal	5.45	3.41	.65	1.05
6.Betal	5.59	4.93	8.08	2.46
7.Betal	3.68	2.40	.80	1.01
8.Betal	4.44	3.60	5.65	2.05
1.Beta2	3.87	6.30	11.66	3.38
2.Beta2	3.12	6.35	64.43	7.44
3.Beta2	7.08	9.89	14.89	3.52
4.Beta2	6.07	8.38	18.88	3.93
5.Beta2	8.80	9.31	10.52	2.88
6.Beta2	8.99	11.59	12.03	3.22
7.Beta2	4.61	4.35	4.38	2.10
8.Beta2	6.29	7.47	19.76	3.70

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Betal = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B2
Descriptive Statistics of Relative Power(RP) EEG Collected
During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	49.29	17.98	-.14	-.40
2.Delta	52.52	15.90	-.15	-.29
3.Delta	31.41	14.23	.22	.68
4.Delta	34.18	15.64	.55	.80
5.Delta	18.32	10.09	4.21	1.64
6.Delta	16.66	8.72	1.59	1.15
7.Delta	14.28	10.97	11.41	2.85
8.Delta	12.02	7.00	2.56	1.54
1.Theta	20.30	6.81	.02	.35
2.Theta	20.03	5.64	-.06	-.07
3.Theta	15.94	5.42	-.23	.23
4.Theta	15.98	5.40	.88	.39
5.Theta	13.59	5.56	-.50	.45
6.Theta	12.75	5.29	-.51	.39
7.Theta	13.95	6.55	.00	.74
8.Theta	12.32	5.98	2.21	1.31
1.Alpha	13.13	9.12	7.50	2.29
2.Alpha	11.62	6.24	.30	.80
3.Alpha	19.39	10.65	2.27	1.41
4.Alpha	19.54	10.41	.02	.85
5.Alpha	39.38	18.74	-1.03	.20
6.Alpha	42.68	19.16	-.96	.13
7.Alpha	47.19	20.09	-1.00	-.03
8.Alpha	48.38	18.54	-.97	-.06
1.Betal	5.58	3.35	1.09	.94
2.Betal	5.17	2.98	-.22	.57
3.Betal	10.49	4.36	3.76	1.02
4.Betal	9.59	4.06	.19	.22
5.Betal	11.29	5.77	1.27	1.20
6.Betal	11.06	5.84	3.87	1.40
7.Betal	10.89	5.93	.11	.81
8.Betal	11.51	5.73	.08	.76
1.Beta2	11.71	12.89	7.34	2.55
2.Beta2	10.67	11.06	10.11	2.84
3.Beta2	22.78	15.72	.69	1.06
4.Beta2	20.71	15.25	.24	1.00
5.Beta2	17.42	12.71	1.58	1.31
6.Beta2	16.85	12.94	1.14	1.28
7.Beta2	13.69	10.82	2.04	1.53
8.Beta2	15.78	11.67	2.21	1.42

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Betal = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B3
Descriptive Statistics of Log10(AP) EEG Collected During
CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	1.11	.42	-.29	.33
2.Delta	1.11	.37	.23	.44
3.Delta	.82	.25	.84	.50
4.Delta	.86	.29	1.06	.95
5.Delta	.85	.22	.78	.61
6.Delta	.80	.25	.76	.79
7.Delta	.57	.30	.65	.68
8.Delta	.54	.26	-.26	-.01
1.Theta	.74	.33	.26	.62
2.Theta	.70	.30	.18	.60
3.Theta	.54	.22	.13	.46
4.Theta	.55	.24	.90	.47
5.Theta	.74	.27	.78	.83
6.Theta	.70	.32	2.06	1.16
7.Theta	.59	.33	-.11	.17
8.Theta	.57	.31	.17	.25
1.Alpha	.49	.27	.84	.66
2.Alpha	.42	.25	.36	.53
3.Alpha	.60	.26	-.27	.36
4.Alpha	.60	.30	.18	-.02
5.Alpha	1.19	.46	-.80	.04
6.Alpha	1.21	.49	-.15	.24
7.Alpha	1.12	.51	-.52	.00
8.Alpha	1.17	.46	-.49	-.13
1.Beta1	.11	.29	1.51	.88
2.Beta1	.03	.26	2.05	.76
3.Beta1	.35	.29	-.40	.24
4.Beta1	.30	.28	1.48	.27
5.Beta1	.65	.28	-.58	-.24
6.Beta1	.62	.32	-.19	.22
7.Beta1	.47	.31	-.75	-.27
8.Beta1	.53	.32	-.44	.09
1.Beta2	.32	.42	.91	1.02
2.Beta2	.27	.37	2.42	.95
3.Beta2	.62	.43	.12	.44
4.Beta2	.56	.42	.03	.37
5.Beta2	.78	.38	-.17	.18
6.Beta2	.74	.41	-.05	.39
7.Beta2	.52	.35	-.33	.25
8.Beta2	.61	.39	-.24	.38

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Beta1 = region 5 (left temporal) beta1 (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B4
Descriptive Statistics of the LOG10(RP/1-RP) EEG Collected
During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	-.03	.38	1.01	-.74
2.Delta	.04	.32	1.35	-.53
3.Delta	-.38	.31	.59	-.06
4.Delta	-.32	.34	1.54	-.03
5.Delta	-.70	.28	.59	.50
6.Delta	-.75	.28	.00	.03
7.Delta	-.86	.33	2.36	1.08
8.Delta	-.92	.26	-.27	.62
1.Theta	-.62	.20	.32	-.43
2.Theta	-.62	.17	1.18	-.85
3.Theta	-.75	.19	.98	-.71
4.Theta	-.75	.20	2.46	-.94
5.Theta	-.84	.22	-.40	-.29
6.Theta	-.88	.22	-.26	-.42
7.Theta	-.84	.24	-.61	-.04
8.Theta	-.90	.23	-.20	.33
1.Alpha	-.91	.33	.99	.09
2.Alpha	-.95	.28	-.02	-.34
3.Alpha	-.67	.29	.37	.31
4.Alpha	-.67	.30	-.56	.08
5.Alpha	-.22	.38	-.88	-.06
6.Alpha	-.15	.39	-.66	-.04
7.Alpha	-.06	.41	.06	-.30
8.Alpha	-.04	.36	-.63	-.16
1.Beta1	-1.33	.35	2.32	-1.26
2.Beta1	-1.36	.34	1.43	-1.11
3.Beta1	-.97	.23	2.91	-1.00
4.Beta1	-1.03	.26	2.72	-1.41
5.Beta1	-.95	.24	-.37	.26
6.Beta1	-.96	.26	-.06	.00
7.Beta1	-.98	.28	-.36	-.22
8.Beta1	-.94	.26	-.50	-.16
1.Beta2	-1.08	.52	1.01	.03
2.Beta2	-1.10	.48	1.42	-.12
3.Beta2	-.63	.43	.01	-.02
4.Beta2	-.70	.45	-.21	-.12
5.Beta2	-.78	.39	-.50	.19
6.Beta2	-.81	.41	-.55	.24
7.Beta2	-.91	.38	-.42	.42
8.Beta2	-.83	.38	-.52	.28

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Beta1 = region 5 (left temporal) beta1 (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B5
Descriptive Statistics of Log10(1+AP) EEG Collected During
CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	1.16	.38	-.20	.49
2.Delta	1.16	.34	.36	.61
3.Delta	.89	.22	1.43	.74
4.Delta	.92	.26	1.55	1.14
5.Delta	.92	.19	1.13	.80
6.Delta	.87	.22	1.16	.99
7.Delta	.69	.24	1.50	1.05
8.Delta	.67	.20	-.26	.34
1.Theta	.83	.29	.67	.89
2.Theta	.79	.25	.62	.86
3.Theta	.66	.17	.59	.74
4.Theta	.67	.19	1.52	.88
5.Theta	.83	.24	1.27	1.06
6.Theta	.79	.27	3.04	1.50
7.Theta	.71	.26	.15	.56
8.Theta	.69	.24	.41	.68
1.Alpha	.63	.21	1.78	1.10
2.Alpha	.57	.19	1.08	.95
3.Alpha	.71	.21	.01	.62
4.Alpha	.72	.23	-.06	.42
5.Alpha	1.23	.42	-.83	.17
6.Alpha	1.26	.45	-.09	.43
7.Alpha	1.17	.46	-.48	.20
8.Alpha	1.22	.42	-.58	.06
1.Beta1	.38	.18	4.51	1.78
2.Beta1	.34	.15	8.00	1.98
3.Beta1	.53	.20	-.12	.66
4.Beta1	.50	.19	3.56	1.19
5.Beta1	.75	.23	-.68	.02
6.Beta1	.73	.26	.06	.56
7.Beta1	.62	.22	-.86	.05
8.Beta1	.66	.24	-.25	.45
1.Beta2	.53	.31	2.26	1.58
2.Beta2	.49	.26	5.70	1.94
3.Beta2	.74	.34	.65	.89
4.Beta2	.70	.33	.59	.85
5.Beta2	.86	.32	-.03	.50
6.Beta2	.84	.35	.31	.73
7.Beta2	.66	.27	-.02	.66
8.Beta2	.73	.31	.20	.74

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Beta1 = region 5 (left temporal) beta1 (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B6
Descriptive Statistics of the Square Root (SQRT) of
Absolute Power EEG Collected During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	4.04	2.15	2.55	1.54
2.Delta	3.97	1.93	3.77	1.77
3.Delta	2.69	.88	7.49	2.00
4.Delta	2.86	1.17	6.65	2.22
5.Delta	2.77	.77	4.26	1.63
6.Delta	2.63	.87	4.83	1.83
7.Delta	2.04	.82	6.65	2.06
8.Delta	1.96	.60	.27	.75
1.Theta	2.54	1.13	3.71	1.76
2.Theta	2.39	.94	3.29	1.63
3.Theta	1.93	.52	2.20	1.25
4.Theta	1.95	.58	4.52	1.64
5.Theta	2.48	.91	4.54	1.89
6.Theta	2.42	1.15	10.98	2.85
7.Theta	2.13	.85	2.04	1.26
8.Theta	2.05	.78	2.65	1.38
1.Alpha	1.85	.67	5.51	1.93
2.Alpha	1.69	.54	2.88	1.48
3.Alpha	2.09	.68	1.35	1.13
4.Alpha	2.12	.75	.88	.97
5.Alpha	4.50	2.43	.84	1.05
6.Alpha	4.76	2.99	3.50	1.78
7.Alpha	4.31	2.70	8.06	2.03
8.Alpha	4.42	2.36	2.15	1.21
1.Betal	1.20	.49	9.31	2.49
2.Betal	1.09	.39	17.14	3.04
3.Betal	1.58	.55	.76	1.00
4.Betal	1.50	.55	10.34	2.34
5.Betal	2.23	.71	-.39	.42
6.Betal	2.20	.87	2.00	1.26
7.Betal	1.82	.61	-.54	.36
8.Betal	1.97	.75	1.07	.99
1.Beta2	1.66	1.06	5.54	2.32
2.Beta2	1.52	.91	21.81	3.86
3.Beta2	2.31	1.32	4.65	1.95
4.Beta2	2.15	1.20	5.41	1.96
5.Beta2	2.69	1.26	2.71	1.43
6.Beta2	2.64	1.43	3.81	1.78
7.Beta2	1.97	.86	1.28	1.22
8.Beta2	2.24	1.12	4.13	1.68

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Betal = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B7
Descriptive Statistics of the 1/SQRT(AP) EEG Collected
During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	.31	.14	.38	.75
2.Delta	.30	.12	.67	.77
3.Delta	.41	.11	-.34	.35
4.Delta	.39	.12	-.35	-.05
5.Delta	.39	.09	-.04	.17
6.Delta	.41	.11	.19	.06
7.Delta	.55	.17	-.14	.27
8.Delta	.56	.17	.44	.78
1.Theta	.46	.16	-.33	.33
2.Theta	.47	.15	-.51	.22
3.Theta	.55	.13	-.34	.18
4.Theta	.55	.14	.98	.54
5.Theta	.44	.13	-.19	.04
6.Theta	.47	.15	.04	.05
7.Theta	.54	.20	.65	.82
8.Theta	.55	.19	1.58	.88
1.Alpha	.60	.18	.15	.33
2.Alpha	.64	.18	-.11	.29
3.Alpha	.52	.15	-.46	.31
4.Alpha	.53	.19	3.79	1.34
5.Alpha	.29	.15	.48	.92
6.Alpha	.29	.16	.85	1.08
7.Alpha	.33	.20	.84	1.12
8.Alpha	.30	.17	1.64	1.31
1.Beta1	.93	.28	.49	.28
2.Beta1	1.00	.28	.42	.38
3.Beta1	.71	.23	.22	.55
4.Beta1	.74	.25	2.36	1.14
5.Beta1	.50	.17	.16	.89
6.Beta1	.52	.19	.33	.71
7.Beta1	.62	.23	.04	.88
8.Beta1	.58	.21	.12	.73
1.Beta2	.76	.31	.51	.31
2.Beta2	.80	.31	4.09	1.14
3.Beta2	.55	.26	1.59	.95
4.Beta2	.59	.27	1.33	.95
5.Beta2	.45	.19	.98	.94
6.Beta2	.47	.21	.38	.76
7.Beta2	.60	.24	.06	.67
8.Beta2	.54	.23	-.19	.58

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Beta1 = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B8
Descriptive Statistics of the Cube Root of Absolute Power
EEG Collected During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	2.47	.84	1.21	1.13
2.Delta	2.45	.75	2.12	1.31
3.Delta	1.91	.40	4.31	1.41
4.Delta	1.98	.51	4.14	1.75
5.Delta	1.96	.35	2.70	1.26
6.Delta	1.89	.40	2.95	1.45
7.Delta	1.59	.40	3.72	1.53
8.Delta	1.55	.31	-.04	.50
1.Theta	1.83	.51	2.14	1.36
2.Theta	1.76	.44	1.90	1.27
3.Theta	1.54	.27	1.28	.97
4.Theta	1.55	.30	2.81	1.23
5.Theta	1.81	.42	2.90	1.51
6.Theta	1.77	.51	6.87	2.23
7.Theta	1.63	.42	.97	.88
8.Theta	1.59	.39	1.36	.99
1.Alpha	1.49	.34	3.35	1.47
2.Alpha	1.40	.29	1.76	1.15
3.Alpha	1.62	.34	.60	.86
4.Alpha	1.63	.38	.36	.66
5.Alpha	2.64	.95	-.05	.70
6.Alpha	2.73	1.09	1.76	1.27
7.Alpha	2.55	1.03	2.76	1.13
8.Alpha	2.61	.92	.56	.72
1.Betal	1.11	.28	5.59	1.89
2.Betal	1.05	.23	9.45	2.09
3.Betal	1.34	.31	.18	.75
4.Betal	1.29	.30	5.77	1.54
5.Betal	1.69	.36	-.55	.20
6.Betal	1.66	.43	.91	.90
7.Betal	1.47	.34	-.73	.15
8.Betal	1.55	.39	.28	.68
1.Beta2	1.36	.53	3.66	1.90
2.Beta2	1.29	.45	11.79	2.70
3.Beta2	1.70	.61	2.47	1.42
4.Beta2	1.62	.57	2.65	1.37
5.Beta2	1.89	.57	1.22	.99
6.Beta2	1.86	.64	1.97	1.29
7.Beta2	1.54	.44	.53	.90
8.Beta2	1.67	.54	1.83	1.18

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Betal = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B9
Descriptive Statistics of the Arc Sin(SQRT(RP)) EEG
Collected During CPT1

Variable	<u>M</u>	<u>SD</u>	Kurtosis	Skewness
1.Delta	.78	.20	.29	-.53
2.Delta	.81	.17	.39	-.37
3.Delta	.59	.16	.14	.39
4.Delta	.62	.17	.61	.52
5.Delta	.43	.12	1.98	1.07
6.Delta	.41	.11	.43	.62
7.Delta	.37	.14	6.21	1.98
8.Delta	.34	.10	.82	1.06
1.Theta	.46	.09	-.05	-.02
2.Theta	.46	.07	.28	-.42
3.Theta	.41	.08	.00	-.19
4.Theta	.41	.08	.85	-.19
5.Theta	.37	.08	-.64	.11
6.Theta	.36	.08	-.60	.02
7.Theta	.37	.09	-.51	.37
8.Theta	.35	.09	.60	.81
1.Alpha	.36	.12	3.17	1.23
2.Alpha	.34	.10	-.37	.29
3.Alpha	.44	.13	1.06	.90
4.Alpha	.45	.13	-.42	.50
5.Alpha	.67	.20	-.98	.09
6.Alpha	.71	.21	-.84	.06
7.Alpha	.75	.22	-.68	-.11
8.Alpha	.77	.20	-.82	-.10
1.Betal	.23	.08	.14	.03
2.Betal	.22	.07	-.38	-.12
3.Betal	.32	.07	1.50	.07
4.Betal	.31	.07	.48	-.49
5.Betal	.33	.09	.18	.74
6.Betal	.33	.09	.91	.66
7.Betal	.33	.09	-.50	.34
8.Betal	.34	.09	-.49	.32
1.Beta2	.32	.18	3.25	1.58
2.Beta2	.31	.16	4.19	1.63
3.Beta2	.48	.19	-.01	.63
4.Beta2	.45	.19	-.37	.56
5.Beta2	.41	.16	.27	.78
6.Beta2	.40	.17	.05	.81
7.Beta2	.36	.15	.53	1.01
8.Beta2	.39	.15	.49	.86

Note. 1.Delta = region 1 (left frontal) delta (1-3.5 Hz)
 2.Theta = region 2 (right frontal) theta (3.5-7.5 Hz)
 3.Alpha = region 3 (left fr.-temp.) alpha (7.5-12.5 Hz)
 5.Betal = region 5 (left temporal) betal (12.5-17.5 Hz)
 7.Beta2 = region 7 (left temp-occip) beta2 (17.5-25 Hz)

Table B10
Descriptive Statistics of Relative Power (RP) and
Log10(RP/1-RP) Component Scores Collected During CPT1

Variable	SD	Kurtosis	Skewness	Minimum	Maximum
RP5.1	8.59	1.26	.59	-18.12	27.23
RP5.2	9.36	-.86	.37	-16.40	19.50
RP5.3	6.63	-.30	.58	-11.08	16.64
RP5.4	2.64	.56	.28	-6.21	8.77
RP7.1	6.60	1.27	.63	-13.75	21.30
RP7.2	6.60	-.82	.40	-11.86	14.63
RP7.3	3.30	.10	.77	-5.11	10.08
RP7.4	2.64	.56	.28	-6.21	8.77
RP7.5	3.29	.37	.86	-5.35	10.06
RP8.1	7.32	-.80	.43	-12.83	16.04
RP8.2	6.60	1.27	.63	-13.75	21.30
RP8.3	3.30	.10	.77	-5.11	10.08
RP8.4	2.64	.56	.28	-6.21	8.77
RP8.5	2.60	.69	.94	-4.30	8.53
RP8.6	3.48	.21	.25	-8.94	10.39
RP10.1	5.19	1.72	1.01	-8.83	18.00
RP10.2	4.33	.86	1.03	-5.69	14.12
RP10.3	3.40	-.52	.55	-5.45	8.41
RP10.4	2.64	.56	.28	-6.21	8.77
RP10.5	3.29	.37	.86	-5.35	10.06
RP10.6	2.63	.75	-.89	-8.76	4.62
RP10.9	2.63	.30	.85	-4.00	7.57
LRP5.1	8.84	1.42	-.80	-27.86	18.88
LRP5.2	10.31	-.85	.03	-23.45	20.99
LRP5.3	6.13	-.63	.11	-13.99	12.60
LRP5.4	2.62	.60	-.54	-8.15	6.60
LRP7.1	9.50	1.50	-.79	-29.67	20.43
LRP7.2	6.60	-.82	.07	-15.48	13.00
LRP7.3	3.99	-.64	.18	-8.40	8.71
LRP7.4	2.62	.60	-.54	-8.15	6.60
LRP7.6	2.55	-.38	-.14	-6.11	4.99
LRP7.7	2.47	.43	-.53	-7.60	4.59
LRP9.1	8.16	1.13	-.67	-24.71	18.92
LRP9.2	5.84	-.81	.05	-13.00	11.81
LRP9.3	3.32	-.57	.14	-6.79	7.97
LRP9.4	2.62	.60	-.54	-8.15	6.60
LRP9.6	2.69	-.52	-.10	-6.13	5.61
LRP9.7	2.47	.43	-.53	-7.60	4.59

Note. RP5.1 = component 1 of the RP 5 component extraction.

LRP9.7 = component 7 of the LRP 9 component extraction.

Table B11
Descriptive Statistics of Absolute Power (AP) and
Log10(AP) Component Scores Collected During CPT1

Variable	<u>SD</u>	Kurtosis	Skewness	Minimum	Maximum
AP8.1	6.69	15.56	3.27	-6.18	42.09
AP8.2	5.01	29.91	4.58	-4.38	37.19
AP8.3	6.57	13.24	2.93	-6.33	40.04
AP8.4	3.81	.16	.86	-4.99	11.06
AP8.5	2.63	23.83	3.81	-2.58	18.59
AP8.6	3.58	19.86	3.76	-3.20	23.56
AP12.1	6.69	15.56	3.27	-6.18	42.09
AP12.2	2.76	44.43	5.90	-1.76	22.47
AP12.3	3.63	8.01	2.64	-3.10	16.51
AP12.4	3.58	19.86	3.76	-3.20	23.56
AP12.5	2.67	19.28	3.42	-2.56	17.89
AP12.9	2.44	4.11	1.83	-2.76	10.49
AP12.10	3.54	7.12	2.28	-3.84	16.02
AP12.11	3.53	19.67	3.56	-3.37	23.53
LAP6.1	5.85	-.44	-.05	-13.63	15.36
LAP6.2	3.60	1.67	.80	-8.45	13.77
LAP6.3	6.72	.39	.57	-12.67	23.32
LAP6.4	3.52	-.83	-.09	-7.47	7.39
LAP6.5	6.59	-.34	.01	-16.53	16.07
LAP6.6	6.59	.66	.51	-13.77	21.36

Note. AP8.1 = component 1 of the AP 8 component extraction.
LAP6.6 = component 6 of the LAP 6 component extraction.

Table B12
Descriptive Statistics of Relative Power (RP) and Log10
(RP/1-RP)Component Scores Collected During CPT2

Variable	SD	Kurtosis	Skewness	Minimum	Maximum
RP5.1	8.46	.48	.36	-20.46	22.55
RP5.2	9.14	-.56	.41	-15.82	23.34
RP5.3	6.78	-.18	.73	-11.00	17.93
RP5.4	2.72	.81	.43	-5.22	9.91
RP7.1	6.49	.25	.25	-15.85	18.01
RP7.2	6.52	-.80	.39	-11.55	14.97
RP7.3	3.37	.63	1.08	-5.02	11.21
RP7.4	2.72	.81	.43	-5.22	9.91
RP7.5	3.34	.58	.79	-6.11	10.76
RP8.1	7.16	-.72	.43	-12.61	17.87
RP8.2	6.49	.25	.25	-15.85	18.01
RP8.3	3.37	.63	1.08	-5.02	11.21
RP8.4	2.72	.81	.43	-5.22	9.91
RP8.5	2.65	.73	.85	-4.75	8.75
RP8.6	3.39	1.39	-.03	-9.84	9.70
RP10.1	5.07	.11	.49	-9.40	14.55
RP10.2	4.25	1.38	1.11	-6.11	14.26
RP10.3	3.47	.71	.98	-5.29	11.63
RP10.4	2.72	.81	.43	-5.22	9.91
RP10.5	3.34	.58	.79	-6.11	10.76
RP10.6	2.60	2.50	-1.31	-9.42	4.53
RP10.9	2.58	1.97	1.22	-3.91	10.21
LRP5.1	8.41	1.55	-.77	-32.17	18.57
LRP5.2	10.29	-.70	-.02	-22.76	23.82
LRP5.3	6.24	-.48	.18	-13.14	13.81
LRP5.4	2.70	.25	-.43	-6.85	7.26
LRP7.1	9.01	1.68	-.76	-34.86	19.78
LRP7.2	6.53	-.74	.04	-14.94	14.33
LRP7.3	4.05	-.41	.32	-8.20	9.94
LRP7.4	2.70	.25	-.43	-6.85	7.26
LRP7.6	2.63	-.54	-.07	-5.97	6.79
LRP7.7	2.37	2.03	-.97	-8.37	5.30
LRP9.1	7.78	1.17	-.64	-28.22	18.44
LRP9.2	5.77	-.69	.08	-12.96	13.63
LRP9.3	3.35	-.34	.40	-6.96	8.75
LRP9.4	2.70	.25	-.43	-6.85	7.26
LRP9.6	2.74	-.44	-.04	-6.94	6.15
LRP9.7	2.37	2.03	-.97	-8.37	5.30

Note. RP5.1 = component 1 of the RP 5 component extraction.

LRP9.7 = component 7 of the LRP 9 component extraction.

Table B13
Descriptive Statistics of Absolute Power (AP) and
Log10(AP) Component Scores Collected During CPT2

Variable	<u>SD</u>	Kurtosis	Skewness	Minimum	Maximum
AP8.1	6.75	23.12	3.96	-6.05	47.02
AP8.2	5.14	29.79	4.57	-3.90	38.11
AP8.3	6.41	11.32	2.71	-6.60	37.46
AP8.4	3.97	4.53	1.75	-4.78	17.17
AP8.5	2.63	17.07	3.23	-2.53	17.07
AP8.6	3.41	9.99	2.62	-3.17	19.35
AP12.1	6.75	23.12	3.96	-6.05	47.02
AP12.2	2.80	20.29	3.91	-1.90	18.69
AP12.3	3.39	7.03	2.31	-3.17	17.31
AP12.4	3.41	9.99	2.62	-3.17	19.35
AP12.5	2.63	13.62	2.89	-2.56	16.15
AP12.9	2.44	6.94	2.39	-2.29	12.21
AP12.10	3.54	16.71	3.52	-3.05	21.89
AP12.11	3.50	11.54	2.85	-3.43	20.15
LAP6.1	5.91	-.52	.14	-13.00	15.28
LAP6.2	3.62	.64	.84	-7.09	11.99
LAP6.3	6.55	.58	.70	-12.19	22.36
LAP6.4	3.50	-.28	.01	-7.58	9.07
LAP6.5	6.52	-.19	.44	-12.75	16.13
LAP6.6	6.76	.74	.53	-14.91	23.26

Note. AP8.1 = component 1 of the AP 8 component extraction.
LAP6.6 = component 6 of the LAP 6 component extraction.

Table B14

Descriptive Statistics of Relative Power (RP) and Log10
(RP/1-RP) Component Scores Collected During Resting

Variable	SD	Kurtosis	Skewness	Minimum	Maximum
RP5.1	7.70	-.01	.29	-16.41	20.54
RP5.2	9.33	-.20	.60	-15.51	26.33
RP5.3	7.11	-.67	.52	-11.32	16.88
RP5.4	2.56	-.64	.11	-5.43	6.15
RP7.1	6.12	-.10	.21	-14.22	16.27
RP7.2	6.53	-.33	.57	-11.19	16.67
RP7.3	3.43	.12	.66	-5.50	10.53
RP7.4	2.56	-.64	.11	-5.43	6.15
RP7.5	3.41	-.58	.39	-6.29	8.87
RP8.1	7.17	-.25	.59	-11.96	19.57
RP8.2	6.12	-.10	.21	-14.22	16.27
RP8.3	3.43	.12	.66	-5.50	10.53
RP8.4	2.56	-.64	.11	-5.43	6.15
RP8.5	2.70	-.65	.28	-5.07	6.69
RP8.6	3.39	-.09	.44	-9.13	8.43
RP10.1	5.00	.17	.60	-9.86	13.58
RP10.2	4.43	1.57	1.17	-6.67	16.16
RP10.3	3.59	.23	.68	-5.91	11.50
RP10.4	2.56	-.64	.11	-5.43	6.15
RP10.5	3.41	-.58	.39	-6.29	8.87
RP10.6	2.40	1.07	-1.01	-8.35	3.97
RP10.9	2.56	4.07	1.45	-3.65	12.08
LRP5.1	8.03	.55	-.55	-26.67	16.65
LRP5.2	10.46	-.46	.06	-22.54	25.17
LRP5.3	6.57	-.84	-.01	-12.93	12.72
LRP5.4	2.57	-.49	-.32	-6.57	5.06
LRP7.1	8.50	.57	-.53	-28.61	17.88
LRP7.2	6.60	-.41	-.05	-15.30	14.00
LRP7.3	4.16	-.62	-.08	-8.96	9.15
LRP7.4	2.57	-.49	-.32	-6.57	5.06
LRP7.6	2.58	-.44	.37	-5.27	6.60
LRP7.7	2.29	-.51	-.07	-5.42	4.77
LRP9.1	7.57	.35	-.51	-23.98	14.88
LRP9.2	5.78	-.41	-.03	-13.17	12.64
LRP9.3	3.49	-.45	-.12	-7.69	7.99
LRP9.4	2.57	-.49	-.32	-6.57	5.06
LRP9.6	2.75	-.78	.30	-5.68	5.63
LRP9.7	2.29	-.51	-.07	-5.42	4.77

Note. RP5.1 = component 1 of the RP 5 component extraction.

LRP9.7 = component 7 of the LRP 9 component extraction.

Table B15
Descriptive Statistics of Absolute Power (AP) and
Log10(AP) Component Scores Collected During Resting

Variable	<u>SD</u>	Kurtosis	Skewness	Minimum	Maximum
AP8.1	6.60	19.64	3.53	-6.57	44.27
AP8.2	4.11	1.82	1.32	-5.46	14.25
AP8.3	5.83	4.73	1.86	-7.66	25.21
AP8.4	3.90	.73	1.10	-5.09	11.54
AP8.5	2.57	16.06	3.10	-2.61	16.44
AP8.6	3.17	3.31	1.71	-3.59	13.07
AP12.1	6.60	19.64	3.53	-6.57	44.27
AP12.2	2.59	5.21	2.16	-2.51	10.81
AP12.3	3.30	15.10	3.19	-3.31	20.52
AP12.4	3.17	3.31	1.71	-3.59	13.07
AP12.5	2.60	11.29	2.77	-2.63	14.95
AP12.9	2.59	3.77	1.76	-2.88	11.29
AP12.10	3.32	4.91	1.75	-4.28	15.92
AP12.11	3.23	3.51	1.61	-4.36	13.25
LAP6.1	6.15	-.45	-.34	-14.94	14.20
LAP6.2	3.58	.01	.53	-6.54	10.00
LAP6.3	6.32	.33	.23	-14.86	17.68
LAP6.4	3.59	-.51	-.18	-8.44	7.16
LAP6.5	6.48	-.73	-.14	-14.00	13.61
LAP6.6	6.80	.49	.27	-14.99	21.84

Note. AP8.1 = component 1 of the AP 8 component extraction.
LAP6.6 = component 6 of the LAP 6 component extraction.

Table B16
Descriptive Statistics of Relative Power (RP) and
Log10(RP/1-RP) CPT1-CPT2 Component Change Scores

Variable	<u>SD</u>	Kurtosis	Skewness	Minimum	Maximum
CRP5.1	8.77	.93	.58	-19.95	29.41
CRP5.2	8.01	.25	-.32	-22.21	19.93
CRP5.3	6.66	1.02	-.94	-20.04	13.07
CRP5.4	2.73	-.38	-.18	-6.82	5.82
CRP7.1	6.67	.58	.27	-15.63	20.40
CRP7.2	5.62	.05	-.43	-15.02	12.07
CRP7.3	3.16	.17	-.23	-7.18	7.66
CRP7.4	2.73	-.38	-.18	-6.82	5.82
CRP7.5	3.42	2.26	-.14	-13.46	9.94
CRP8.1	6.21	.17	-.29	-16.32	15.87
CRP8.2	6.67	.58	.27	-15.63	20.40
CRP8.3	3.16	.17	-.23	-7.18	7.66
CRP8.4	2.73	-.38	-.18	-6.82	5.82
CRP8.5	2.73	2.18	.58	-8.78	9.12
CRP8.6	3.64	1.37	-1.09	-10.30	8.15
CRP10.1	5.05	.99	.22	-13.46	16.04
CRP10.2	4.46	1.62	-.86	-16.96	8.38
CRP10.3	3.79	-.02	.11	-8.98	9.85
CRP10.4	2.73	-.38	-.18	-6.82	5.82
CRP10.5	3.42	2.26	-.14	-13.46	9.94
CRP10.6	2.51	2.20	-.77	-8.12	6.61
CRP10.9	2.34	3.26	.77	-7.68	9.00
CLRP5.1	9.15	2.63	-.90	-36.50	19.70
CLRP5.2	7.46	-.16	.34	-17.53	19.20
CLRP5.3	6.38	.72	-.69	-18.52	14.15
CLRP5.4	2.73	.03	-.59	-7.26	4.69
CLRP7.1	9.89	2.41	-.84	-38.66	21.13
CLRP7.2	5.40	-.09	.21	-12.17	14.60
CLRP7.3	3.99	.40	-.45	-10.69	9.05
CLRP7.4	2.73	.03	-.59	-7.26	4.69
CLRP7.6	1.99	.33	-.22	-6.02	4.88
CLRP7.7	2.45	-.20	-.36	-6.14	4.90
CLRP9.1	8.34	2.42	-.79	-32.79	18.78
CLRP9.2	4.57	.05	.37	-10.00	13.73
CLRP9.3	3.34	-.03	-.08	-8.56	8.00
CLRP9.4	2.73	.03	-.59	-7.26	4.69
CLRP9.6	2.87	1.35	.28	-8.02	8.90
CLRP9.7	2.45	-.20	-.36	-6.14	4.90

Note. CRP5.1 = change in component scores (CPT1-CPT2) of
component 1 Relative Power 5 component extraction.

Table B17
Descriptive Statistics of Absolute Power (AP) and
Log10(AP) CPT1-CPT2 Component Change Scores

Variable	<u>SD</u>	Kurtosis	Skewness	Minimum	Maximum
CAP8.1	6.03	7.83	-.47	-30.95	20.10
CAP8.2	5.13	10.07	2.97	-7.29	23.86
CAP8.3	7.22	5.99	2.42	-6.74	31.48
CAP8.4	4.08	1.96	.69	-9.64	13.36
CAP8.5	2.54	12.71	-2.48	-15.19	6.01
CAP8.6	3.27	4.84	1.09	-9.28	12.38
CAP12.1	6.03	7.83	-.47	-30.95	20.10
CAP12.2	2.74	11.15	3.15	-4.98	13.11
CAP12.3	3.66	7.54	2.56	-4.08	17.55
CAP12.4	3.27	4.84	1.09	-9.28	12.38
CAP12.5	2.19	11.54	-2.21	-12.62	5.03
CAP12.9	2.42	7.00	1.62	-4.89	11.17
CAP12.10	3.38	7.26	1.86	-7.20	16.48
CAP12.11	3.67	5.74	2.41	-3.85	14.24
CLAP6.1	6.12	.41	.79	-11.54	17.91
CLAP6.2	3.58	1.86	.54	-8.66	13.14
CLAP6.3	7.05	1.33	.89	-14.32	24.98
CLAP6.4	3.73	-.18	.59	-6.85	9.88
CLAP6.5	7.02	.14	.59	-14.45	19.67
CLAP6.6	7.12	-.23	.20	-19.30	15.62

Note. CAP6.1 = change in component scores (CPT1-CPT2) of
component 1 Absolute Power 6 component extraction

Table B18
Correlations of Component Scores From Six Component
Log10(AP) Solution Multiple Regression on CPT1-CPT2
Omission Error Change Scores

	6.1	6.2	6.3	6.4	6.5
6.2	.014				
6.3	.235	-.123			
6.4	.404	.136	-.051		
6.5	.129	.459	-.030	.340	
6.6	.570	-.093	.352	.224	.054

Table B19

Standard Multiple Regression of Component Scores From Six Component Log10(AP) Solution on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
6.6	.184608	.125550	.145103	2.127	.1480
6.5	-.084583	-.035340	-.071224	.513	.4758
6.3	.051967	.089275	.047727	.230	.6325
6.4	-.106771	-.094405	-.091457	.845	.3603
6.2	.183637	.105947	.161031	2.620	.1088
6.1	-.055841	.009963	-.042820	.185	.6679
Multiple R		.24451	F (8,93) =		1.00679
R squared		.05979	p =		.4256
Adjusted R squared		.00040			

Table B20

Standard Multiple Regression of Component Scores From Five Component Relative Power (RP) Solution on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
5.4	-.039185	-.023523	-.037764	.143	.7062
5.3	.169797	.168237	.166962	2.794	.0978
5.1	.021525	-.032355	.018739	.035	.8516
5.2	-.066728	-.053513	-.057849	.335	.5638
Multiple R		.17990	F (4,97) =		.81103
R squared		.03236	p =		.5211
Adjusted R squared		-.00754			

Table B21

Correlations of Component Scores From Five Component Relative Power (RP) Solution Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	5.1	5.2	5.3
5.2	.463		
5.3	-.176	-.041	
5.4	-.175	-.259	.013

Table B22

Standard Multiple Regression of Component Scores From Ten Component Relative Power (RP) Solution on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	<u>F</u>	<u>p</u>
10.9	-.110911	-.102962	-.085874	.728	.3956
10.5	-.067730	-.036515	-.057434	.326	.5695
10.3	.098635	.092407	.091593	.829	.3650
10.4	.047436	-.023523	.038816	.149	.7005
10.1	.100324	.045795	.082607	.674	.4137
10.2	-.136950	-.086403	-.105707	1.104	.2962
10.6	-.178114	-.056029	-.123314	1.502	.2234
Multiple <u>R</u>		.21977	<u>F</u> (7,94) =		.68149
<u>R</u> squared		.04830	<u>p</u> =		.6873
Adjusted <u>R</u> squared		-.02257			

Table B23

Correlations of Component Scores From Ten Component Relative Power (RP) Solution Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	10.1	10.2	10.3	10.4	10.5	10.6
10.2	.320					
10.3	-.081	-.108				
10.4	-.140	-.167	.118			
10.5	.296	-.136	.023	.325		
10.6	-.343	-.495	.283	.519	.237	
10.9	.335	.544	-.302	-.208	-.068	-.471

Table B24

Standard Multiple Regression of Component Scores From Five Component Log10(RP/1-RP) Solution on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
5.4	-.090179	-.040856	-.082695	.682	.4109
5.3	.127080	.126831	.122649	1.500	.2236
5.1	.011114	-.034174	.010499	.011	.9167
5.2	-.102975	-.076535	-.092678	.857	.3570
Multiple R		.16524	F (4,97) =		.68070
R squared		.02730	p =		.6070
Adjusted R squared		-.01281			

Table B25

Correlations of Component Scores From Five Component Log10(RP/1-RP) Solution Multiple Regression on CPT1-CPT2 Omission Error Change Scores

	5.1	5.2	5.3
5.2	.226		
5.3	-.257	-.093	
5.4	-.117	-.396	.077

Table B26

Standard Multiple Regression of Component Scores From Five Component Log10(RP/1-RP) Solution on Change in Percent Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
7.7	-.266756	-.091825	-.186842	3.578	.0616
7.3	.137388	.112501	.132921	1.811	.1816
7.1	-.070239	-.042761	-.060119	.370	.5442
7.2	-.185426	-.139753	-.145200	2.161	.1449
7.4	-.013437	-.040856	-.010882	.012	.9125
7.6	-.093546	-.040060	-.066417	.452	.5030
Multiple R		.27049	F (6,96) =		1.24990
R squared		.07317	p =		.2881
Adjusted R squared		.01463			

Table B27

Correlations of Component Scores From Seven Component
Log10(RP/1-RP) Solution Multiple Regression on CPT1-CPT2
Omission Error Change Scores

	7.1	7.2	7.3	7.4	7.6
7.2	.277				
7.3	-.156	-.089			
7.4	-.138	-.332	.032		
7.6	-.064	.529	.034	-.458	
7.7	-.347	-.459	.183	.547	-.510

Table B28

Standard Multiple Regression of Component Scores From Nine
Component Log10(RP/1-RP) Solution on Change in Percent
Omission Errors (CPT1-CPT2)

Component	Beta	r	Semi Partial Correlation	F	p
9.7	-.238277	-.091825	-.166030	2.826	.0961
9.3	.165119	.139750	.154663	2.452	.1207
9.1	-.014408	-.011821	-.012004	.015	.9035
9.2	-.214140	-.133397	-.173270	3.077	.0826
9.4	.005762	-.040856	.004627	.002	.9627
9.6	-.010723	.022743	-.007509	.006	.9396
Multiple R		.27058	F (6,95) =		1.25076
R squared		.07321	p =		.2877
Adjusted R squared		.01468			

Table B29.

Correlations of Component Scores From Nine Component
Log10(RP/1-RP) Solution Multiple Regression on CPT1-CPT2
Omission Error Change Scores

	9.1	9.2	9.3	9.4	9.6
9.2	.242				
9.3	-.149	-.113			
9.4	-.119	-.310	.066		
9.6	-.188	.452	.129	-.457	
9.7	-.326	-.460	.213	.547	-.458

Appendix C1

Relative Power 5 Components

Relative Power 6 Components

Relative Power 7 Components

Notes: A = Alpha, B1 = Beta1, B2 = Beta2, T = Theta, D = Delta.
 Variables in parentheses i.e., (A) indicates a complex component.
 % indicates percent of total variance accounted for by component.
 (*) indicates that this component was dropped from analysis
 because it had less than 3 variables loading at .60 or greater.

Relative Power 8 Components

Relative Power 9 Components

Relative Power 10 Components

Notes: A = alpha, B1 = beta1, B2 = beta2, T = Theta, S = Sigma.
 (A) indicates a complex component.
 (B) indicates a component that total variance accounted for by component.
 (C) indicates that this component was dropped from analysis
 because of a low variable loading at .60 or greater.

Log10(RP/1-RP) 8 Components

Log10(RP/1-RP) 9 Components

Log10(RP/1-RP) 10 Components

*** = Total, RP = Ratio, T = Total, D = Delta.
 (A) indicates a simple component.
 (B) indicates percent of total variance accounted for by this component.
 (C) indicates that this component was dropped from analysis.
 (D) indicates fewer than 7 variables loading at .60 or greater.

Absolute Power & Components

Absolute Power & Components

Absolute Power & Components

Absolute Power & Components

Figure 1: A series of 10 small plots showing data points and curves for various parameters.

Figure 3: A series of 10 small plots showing data points and curves for various parameters. The plots are arranged in two rows of five. The top row plots show data for parameters B1, B2, B3, B4, and B5. The bottom row plots show data for parameters B6, B7, B8, B9, and B10. Each plot has a horizontal axis labeled with a parameter name and a vertical axis labeled with a numerical value. The data points are represented by small circles, and the curves are represented by solid lines.

Figure 1: A series of 10 vertical plots showing the results of a statistical analysis.

Figure 2: A series of 10 vertical plots showing the results of a statistical analysis.

Appendix D1
VARIMAX ROTATED COMPONENT PATTERN

	1	2	3	4	5	6
1.A	0.034	0.100	0.041	0.016	-0.012	-0.068
2.A	0.359	0.302	0.231	0.036	0.164	0.155
3.A	0.366	0.011	-0.058	-0.036	0.309	-0.019
4.A	0.451	0.277	0.083	0.216	0.480	0.104
5.A	0.783	-0.101	0.109	0.044	0.256	-0.010
6.A	0.713	-0.090	0.199	0.182	0.404	0.066
7.A	0.216	-0.011	0.048	-0.006	0.854	0.163
8.A	0.145	-0.033	-0.040	0.027	0.947	0.058
1.D	0.056	-0.079	0.928	-0.058	0.055	-0.027
2.D	0.026	-0.051	0.954	-0.044	-0.012	-0.008
3.D	0.032	-0.062	0.583	-0.070	0.015	-0.015
4.D	0.041	-0.009	0.575	-0.083	0.064	-0.027
5.D	0.629	0.000	0.307	-0.027	-0.085	0.054
6.D	0.910	-0.035	0.127	0.060	0.038	0.094
7.D	0.223	-0.039	0.080	-0.033	0.197	0.064
8.D	0.317	0.021	0.099	0.051	0.648	0.092
1.T	0.018	-0.049	0.724	-0.043	0.007	-0.047
2.T	0.057	0.006	0.848	-0.021	-0.031	0.042
3.T	0.194	0.003	0.322	-0.030	0.005	-0.020
4.T	0.209	0.082	0.385	-0.025	0.012	0.044
5.T	0.846	0.019	0.027	0.031	-0.013	0.029
6.T	0.943	-0.048	-0.060	0.073	0.026	0.039
7.T	0.685	0.029	-0.078	0.045	0.345	0.105
8.T	0.774	0.036	-0.122	0.146	0.436	0.031
1.B1	-0.098	0.418	-0.009	0.196	-0.088	-0.016
2.B1	-0.023	0.892	-0.068	0.075	0.012	0.093
3.B1	0.018	0.357	-0.014	0.167	-0.060	0.003
4.B1	0.050	0.166	-0.069	0.940	0.036	0.077
5.B1	0.286	-0.070	0.008	0.161	0.014	0.336
6.B1	0.334	-0.150	-0.051	0.704	0.035	0.301
7.B1	0.195	-0.067	-0.039	0.062	0.283	0.841
8.B1	0.229	-0.163	-0.095	0.187	0.263	0.416
1.B2	-0.112	0.721	-0.070	0.380	-0.018	-0.128
2.B2	-0.039	0.924	-0.065	0.068	-0.009	-0.019
3.B2	0.009	0.546	-0.018	0.168	-0.017	-0.119
4.B2	0.033	0.270	-0.101	0.916	0.044	-0.028
5.B2	0.111	0.280	0.047	0.139	-0.045	0.095
6.B2	0.165	0.040	0.018	0.759	0.017	0.043
7.B2	-0.012	0.060	0.010	0.084	0.014	0.901
8.B2	0.074	0.026	0.023	0.146	0.091	0.289

	7	8	9	10	11	12
1.A	0.527	-0.044	0.721	-0.012	0.098	0.222
2.A	-0.154	0.021	0.636	0.142	0.172	-0.003
3.A	0.034	0.098	0.672	0.183	0.095	0.129
4.A	-0.081	-0.120	0.513	0.063	0.048	-0.148
5.A	-0.084	0.088	0.188	0.113	-0.162	-0.184
6.A	0.000	-0.343	0.144	0.082	-0.157	-0.010
7.A	-0.017	-0.155	0.172	-0.079	-0.080	0.107
8.A	0.030	0.037	0.080	-0.026	0.022	0.049
1.D	0.028	0.037	-0.069	-0.012	0.160	-0.049
2.D	-0.073	-0.019	-0.035	-0.030	0.109	0.071
3.D	-0.019	-0.060	-0.133	-0.034	0.707	0.034
4.D	0.008	-0.097	-0.132	-0.128	0.664	0.057
5.D	-0.001	0.579	0.092	-0.036	0.061	0.212
6.D	0.099	-0.032	-0.011	0.032	0.168	0.131
7.D	0.010	0.079	0.146	-0.012	0.100	0.878
8.D	0.081	0.493	-0.058	0.006	0.219	0.230
1.T	0.485	0.110	0.224	0.031	0.234	-0.062
2.T	-0.089	0.068	0.249	0.080	0.282	0.064
3.T	0.005	0.213	0.348	0.150	0.747	0.092
4.T	-0.054	0.062	0.281	0.057	0.767	0.058
5.T	-0.005	0.404	0.190	0.063	0.084	0.023
6.T	0.041	-0.142	0.047	0.101	0.108	0.064
7.T	-0.038	0.122	0.152	-0.003	0.200	0.430
8.T	0.060	0.114	0.050	0.107	0.175	0.112
1.B1	0.784	0.064	0.204	0.085	-0.025	0.099
2.B1	0.018	-0.007	0.231	0.234	0.050	-0.012
3.B1	0.107	0.049	0.172	0.822	0.059	0.167
4.B1	-0.008	0.049	0.109	0.129	-0.006	-0.001
5.B1	0.095	0.207	0.146	0.744	-0.003	-0.166
6.B1	0.250	-0.129	0.041	0.254	-0.045	-0.042
7.B1	0.108	0.199	0.071	0.140	0.067	0.067
8.B1	0.441	0.101	-0.157	0.450	0.056	-0.046
1.B2	0.414	0.082	-0.029	0.155	-0.037	0.006
2.B2	0.045	-0.017	0.016	0.229	-0.016	-0.035
3.B2	0.084	-0.067	-0.014	0.768	0.011	0.034
4.B2	0.020	0.048	-0.097	0.149	-0.030	0.010
5.B2	0.135	-0.143	0.024	0.851	-0.005	-0.061
6.B2	0.538	-0.075	0.007	0.103	-0.096	-0.026
7.B2	0.061	-0.114	-0.007	0.040	-0.050	0.034
8.B2	0.820	-0.044	-0.075	0.269	-0.073	-0.088

Appendix D2
OBLIQUE FACTOR PATTERN

	1	2	3	4	5	6
1.A	0.095	0.144	0.064	0.097	0.040	-0.021
2.A	0.454	0.276	0.282	0.159	0.296	0.264
3.A	0.464	0.012	-0.010	0.093	0.428	0.154
4.A	0.598	0.237	0.130	0.365	0.615	0.287
5.A	0.820	-0.202	0.145	0.177	0.457	0.214
6.A	0.842	-0.169	0.239	0.308	0.602	0.301
7.A	0.401	-0.078	0.064	0.080	0.896	0.323
8.A	0.325	-0.087	-0.035	0.107	0.953	0.236
1.D	0.108	-0.131	0.935	-0.125	0.051	-0.007
2.D	0.076	-0.089	0.956	-0.128	-0.016	-0.012
3.D	0.076	-0.085	0.655	-0.154	0.022	-0.015
4.D	0.082	-0.042	0.644	-0.164	0.065	-0.037
5.D	0.570	-0.119	0.300	0.036	0.105	0.147
6.D	0.917	-0.162	0.181	0.191	0.312	0.276
7.D	0.285	-0.051	0.065	-0.007	0.298	0.122
8.D	0.411	-0.075	0.080	0.131	0.729	0.246
1.T	0.076	-0.077	0.733	-0.043	0.019	-0.007
2.T	0.130	-0.010	0.874	-0.066	0.000	0.066
3.T	0.248	0.007	0.404	-0.021	0.088	0.056
4.T	0.268	0.068	0.478	-0.025	0.097	0.096
5.T	0.804	-0.097	0.058	0.167	0.235	0.200
6.T	0.947	-0.150	0.006	0.224	0.303	0.243
7.T	0.745	-0.058	-0.042	0.166	0.558	0.279
8.T	0.845	-0.062	-0.086	0.309	0.654	0.269
1.B1	-0.085	0.437	-0.070	0.327	-0.077	-0.025
2.B1	-0.015	0.902	-0.100	0.254	0.018	0.058
3.B1	0.093	0.440	-0.065	0.350	-0.009	0.108
4.B1	0.177	0.240	-0.119	0.962	0.131	0.179
5.B1	0.388	-0.082	-0.017	0.342	0.167	0.516
6.B1	0.480	-0.148	-0.074	0.794	0.229	0.475
7.B1	0.332	-0.187	-0.059	0.188	0.447	0.916
8.B1	0.355	-0.222	-0.131	0.347	0.397	0.581
1.B2	-0.113	0.758	-0.151	0.510	-0.041	-0.145
2.B2	-0.066	0.930	-0.114	0.237	-0.033	-0.069
3.B2	0.055	0.622	-0.073	0.358	-0.007	-0.036
4.B2	0.127	0.341	-0.168	0.946	0.109	0.058
5.B2	0.198	0.328	0.010	0.338	0.026	0.221
6.B2	0.272	0.066	-0.036	0.832	0.132	0.167
7.B2	0.095	-0.033	-0.017	0.165	0.130	0.863
8.B2	0.156	-0.022	-0.030	0.305	0.169	0.373

	7	8	9	10	11	12
1.A	0.446	0.116	0.692	0.106	0.158	0.257
2.A	-0.188	0.217	0.806	0.295	0.274	0.006
3.A	-0.040	0.293	0.783	0.294	0.149	0.134
4.A	-0.105	0.023	0.696	0.268	0.089	-0.123
5.A	-0.135	0.220	0.403	0.258	-0.070	-0.216
6.A	-0.017	-0.179	0.342	0.232	-0.055	-0.037
7.A	-0.063	-0.079	0.294	0.012	-0.011	0.142
8.A	-0.004	0.079	0.207	0.056	0.062	0.102
1.D	0.017	0.105	0.043	-0.040	0.436	-0.035
2.D	-0.073	0.055	0.066	-0.076	0.400	0.069
3.D	-0.028	0.091	-0.026	-0.067	0.839	0.137
4.D	-0.017	0.051	-0.023	-0.149	0.799	0.177
5.D	-0.040	0.746	0.322	0.105	0.272	0.195
6.D	0.065	0.224	0.255	0.219	0.282	0.144
7.D	-0.001	0.294	0.264	0.016	0.267	0.871
8.D	0.073	0.600	0.168	0.138	0.353	0.273
1.T	0.440	0.217	0.283	0.083	0.463	-0.027
2.T	-0.095	0.206	0.364	0.079	0.542	0.068
3.T	-0.027	0.450	0.488	0.204	0.849	0.172
4.T	-0.084	0.300	0.432	0.120	0.867	0.157
5.T	-0.054	0.604	0.444	0.258	0.189	0.015
6.T	0.005	0.105	0.289	0.278	0.151	0.066
7.T	-0.073	0.372	0.396	0.160	0.293	0.459
8.T	0.042	0.319	0.321	0.308	0.223	0.140
1.B1	0.805	0.098	0.208	0.258	0.012	0.114
2.B1	0.067	0.046	0.370	0.381	0.046	0.009
3.B1	0.233	0.155	0.298	0.867	0.102	0.060
4.B1	0.184	0.007	0.150	0.334	-0.061	-0.077
5.B1	0.202	0.295	0.278	0.854	0.036	-0.309
6.B1	0.399	-0.082	0.103	0.471	-0.069	-0.146
7.B1	0.169	0.284	0.174	0.331	0.114	0.003
8.B1	0.534	0.164	-0.053	0.598	0.071	-0.123
1.B2	0.509	0.047	0.050	0.321	-0.046	0.019
2.B2	0.104	-0.007	0.160	0.347	-0.022	-0.012
3.B2	0.212	-0.009	0.135	0.807	0.028	-0.042
4.B2	0.224	-0.021	-0.034	0.334	-0.090	-0.054
5.B2	0.264	-0.057	0.156	0.900	0.025	-0.177
6.B2	0.670	-0.081	0.036	0.330	-0.098	-0.084
7.B2	0.149	-0.090	0.006	0.190	-0.039	-0.040
8.B2	0.871	-0.013	-0.045	0.436	-0.034	-0.129

Appendix D3
12-Component, Absolute-Power Oblique Rotation

$\begin{array}{c} \\ + \\ \\ + \\ A \mid (A) \\ T \mid DT \\ + \\ T \mid T \\ \\ 1 \end{array}$	$\begin{array}{c} B2 \mid B1 \\ B2 \mid B2 \\ + \\ \\ + \\ \\ + \\ \\ 2 \end{array}$	$\begin{array}{c} D \mid D \\ T \mid T \\ + \\ (D) \mid \\ + \\ \\ + \\ \\ 3 \end{array}$	$\begin{array}{c} \\ + \\ B1 \\ B2 \\ + \\ B1 \\ B2 \\ + \\ \\ 4 \end{array}$	$\begin{array}{c} \\ + \\ A \\ + \\ (A) \\ + \\ A \mid A \\ D \mid D \\ \\ 5 \end{array}$	$\begin{array}{c} \\ + \\ \\ + \\ \\ + \\ B1 \\ B2 \\ \\ 6 \end{array}$
$\begin{array}{c} B1 \mid \\ + \\ \\ + \\ B2 \\ + \\ B2 \\ \\ 7 \end{array}$	$\begin{array}{c} \\ + \\ \\ + \\ D \mid T \\ + \\ D \\ \\ 8 \end{array}$	$\begin{array}{c} A \mid A \\ + \\ A \mid (A) \\ + \\ \\ + \\ \\ 9 \end{array}$	$\begin{array}{c} \\ + \\ B1 \\ B2 \\ + \\ B1 \\ B2 \\ + \\ \\ 10 \end{array}$	$\begin{array}{c} \\ + \\ (D) \mid D \\ T \mid T \\ + \\ \\ + \\ \\ 11 \end{array}$	$\begin{array}{c} \\ + \\ \\ + \\ \\ + \\ D \\ \\ 12 \end{array}$

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