UNIVERSITY OF ALBERTA

# EEG PATTERNS AND T.O.V.A.™ PARAMETERS

# IN

# 11 TO 13 YEAR OLD BOYS

by

**Ahmed I. Hassan**

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND

RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF EDUCATION

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

SPRING, 1995

ISBN 0-612-01542-4

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: AHMED IBRAHIM HASSAN

TITLE OF THESIS: EEG BANDS AND T.O.V.A.™ PARAMETERS

DEGREE: MASTER OF EDUCATION

YEAR THIS DEGREE GRANTED: 1995



Ahmed I. Hassan
11746 - 29 Avenue
Edmonton, Alberta
Canada, T6J-3K9

March 23, 1995

Date

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled: EEG BANDS AND T.O.V.A.™ PARAMETERS IN 11 TO 13 YEAR OLD BOYS, submitted by AHMED IBRAHIM HASSAN in partial fulfillment of the requirements for the degree of MASTER OF EDUCATION.

Dr. G. W. Fitzsimmons (Supervisor)

Dr. H. Zingle (Dean)

Dr. D. A. Mackay (Associate Dean)

Date: March 23, 1995

All Praise is Due to ALLAH

The LORD and CREATOR of the Universe and All That Dwells Within It

Verily, I Have Accomplished Nothing Except That

Which HE Has Already Pre-ordained For Me

Any Knowledge Which I Have Acquired,

It is HE Who Has Bestowed It Upon Me

There Is No Power, Except HIS Power

It Is HE Whom I Thank, Worship And Praise

## Abstract

Pearson product moment correlations were computed between each of four T.O.V.A.™ parameters and the average magnitude of each of nine EEG bands. The T.O.V.A.™ parameters were: errors of omission (%EO), errors of commission (%EC), reaction time (RT), and reaction time variability (RTV). The EEG bands used in this study were Delta, Theta, Alpha, SMR, Beta1, Beta2, Beta_All, EMG, and Total_EEG. The nine sites used in this study were C3, C4, CZ, FZ, O1, O2, P3, P4, and PZ (electrodes were placed according to the international 10-20 system). In addition, two multiple stepwise regression equations were computed, using the T.O.V.A.™ parameters of %EO and %EC as dependent variables and the above-mentioned EEG bands across sites as independent variables. The sample for this study consisted of seventeen normal (i.e. no ADD or ADHD) fifth and sixth grade boys. Findings indicate that alpha is positively correlated to the T.O.V.A.™ parameters of %EO, %EC, and RTV, and delta is negatively correlated to the same three the T.O.V.A.™ parameters. These findings suggest that attention (as measured by %EO) and impulsivity (as measured by %EC) are a function of cortical alpha and delta levels. Related to this, predictive relationships were found to exist for %EO and %EC, using the EEG bands of alpha, delta, and beta2 as the independent variables.

## Acknowledgments

To my dearest Mother and Father.

Without your love and support, I would not be where I am today.
You deserve the credit for this thesis more than I do.
I love you.

To my dear sister.

Thank you very much for your help in proof-reading this thesis.

To my dear brothers. Life is a series of tests. If you fail one, study harder for the next. But whatever you do, do not fail the final!

To all my friends in the MSA. Thank you for the spiritual support.

To my supervisor, Dr. G. W. Fitzsimmons.

I knew that I could
You believed that I would...
and the rest is history.
Thank you for the opportunity and all the support along the way.

To my colleague, Troy Janzen.

What can I say?
You helped me every step of the way.
So you get this small rhyme
I hope it makes your day.

To Dr. Harvey Zingle

Thank you for taking time out of your busy schedule to be part of my defense committee.

To Dr. Al Mackay

Thank you for the wonderful research opportunity and for being part of my defense committee.

To Jolene and Dan.

Thank you for all your help and support.

To all the secretaries at the Dean's office.

Thank you for putting up with me for this past year.

# TABLE OF CONTENTS

# CHAPTER 1

## INTRODUCTION AND RATIONALE

"Pay attention!" A phrase that, no doubt, has "jump-started" even the greatest minds throughout history. ATTENTION: What is it, and why do teachers always demand that it be paid to them by their students? For that matter, how do the teachers even know when students are not paying enough attention? More importantly, how do the students, themselves, know when they are not paying enough attention? For that matter, what is enough attention?

The fact is, all individuals seem to possess their own, internal, attention monitors. They may not be conscious of these mechanisms, but they use them all the time. These monitors are what alert individuals to the degree of attention which they are paying to others , as well the degree of attention others are paying them. As proof of the existence of this internal mechanism, human language is full of phrases like, "sorry I was not paying attention," and "Johnny! Please pay attention to me!" Such phrases indicate that there is a "sense" within human beings which knows; first, what attention is, and second, how much of it is being given.

The task then is not to prove whether the construct of attention exists, because it is obvious that it does. Rather, the challenge is to try to quantify attention, thus making measurements and comparisons possible.

Ask any school teacher about the criteria to success in academics, and a common response will likely be "paying attention in class". Quantifying attention would provide a valuable measure of an individual's ability to concentrate. Furthermore, if attention can be reliably measured, valid comparisons between individuals becomes possible. The benefits of such comparisons include the ability to diagnose abnormalities in individual attention, the ability to prescribe better remediation, and a greater understanding of the construct of attention.

Much has been learned about the construct of attention over the years. The majority of the research in this area has centered around children with attention deficit disorder (ADD), and attention deficit hyperactivity disorder (ADHD). A review of the literature reveals ADD to be a fairly common childhood disorder, with some 3-5% of school-aged children affected (Barkley, 1990). ADD children typically exhibit maladjustment, and resulting behavioral problems, at home, in school, and among their social groups. As well, ADD children generally exhibit poor academic achievement (Bowley & Walther, 1992, Goldstein & Goldstein, 1990, Barkley, 1990). Other studies, such as, Borden, Brown, Jenkins, and Clingerman (1987), have shown that children with ADD are more likely to suffer depressive symptoms than normal children. Also, recent studies suggest that ADD or ADHD children grow up to be ADD or ADHD adults. These adults are characterized by anti-social behavior, drug and alcohol abuse, and low employability (Weiss & Hechtman, 1993). Goldstein and Goldstein (1990) state, "Disorders of attention and arousal are not cured but must be managed throughout childhood." (pg. 1).

Accurate diagnosis is one of the primary concerns in ADD research today. Many instruments have been developed which attempt to accurately diagnose attention, or the lack thereof. The instruments of concern in this study are: Electroencephalograph (EEG) readings, which monitor and record brain wave activity, and the Test of Variables of Attention (T.O.V.A.™), which is a visual, continuous performance test (CPT) designed to assess individual attention.

EEG readings are electrical impulses which are recorded from locations on the scalp, using special sensors and recording equipment. EEG analysis makes the assumption that individuals with attention deficit have significantly different EEG patterns than normal individuals. Many researchers (Janzen, Graap, Stephanson, Marshall, and Fitzsimmons, 1994; Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992; Janzen, 1992; Lubar, Gross, Shively, & Mann, 1990) have reported that such differences do exist. Each of the aforementioned studies have shown significant differences ($p<0.05$) in EEG patterns between individuals diagnosed as having ADD and normal controls. Diagnosis, then, would be a matter of comparing the EEG pattern of the individual in question with known ADD patterns.

The T.O.V.A.™ was designed to assess attention by evaluating how individuals respond to cues presented on a computer screen. Percent errors of omission (%EO) and percent errors of commission (%EC) are automatically recorded by the computer, as well as response time (RT) and response time variability (RTV). Percent EO, %EC, RT, and RTV are then used to evaluate the individual's attention, relative to his/her norm group.

It is the purpose of this research study to explore the relationship, if any, between EEG readings and the T.O.V.A.™. Since both of the above-mentioned instruments measure individual attention, it is expected that there exist strong relationships between certain parameters of these two measures.

# CHAPTER 2

# LITERATURE REVIEW

## ELECTROENCEPHALOGRAM (EEG)

### INTRODUCTION TO THE HUMAN EEG

Hans Berger, a German neuropsychiatrist is generally credited as being the first to document the human EEG. Since the late 1800's it had been known that the brain's of animals emitted electrical impulses, however it was not until the work of Berger in the 1930's that the human EEG entered the research arena. At that time, Berger was convinced that EEG would lead him to the discovery of the physiological correlate of "mental energy". He theorized that this energy of the mind was created through metabolic processes in the brain and that it could even be transmitted from one person to another. Although Berger never proved his mental energy theory, many of the ideas he postulated, such as the metabolic basis of the EEG rhythm, were surprisingly consistent with currently held views regarding the nature of the EEG rhythm (Niedermeyer, 1993).

Since the 1930's, EEG research has been developing at a rate consistent with the available technology. With the advent of more sophisticated measuring equipment, including powerful micro-computers and more sensitive electrodes, EEG recording equipment became commonplace in every major hospital and research center. Currently, EEG readings are used for many purposes. A few examples of the utility of EEG measures are: medical diagnosis of neurological impairment (Fischer-Williams, 1993), diagnosis of ADD and ADHD children (Janzen, Graap, Stephanson, Marshall, Fitzsimmons, 1994, Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992; Lubar, Gross, Shively, & Mann, 1990), and treatment of children with ADD (Lubar, 1991).

SOURCE OF EEG SIGNALS

As stated earlier, EEG readings measure electrical activity (waves) emitted by the living brain. Although the exact mechanism behind this phenomenon is still unknown, it is generally believed that neural impulses play a major role in the generation and propagation of EEG signals (Niedermeyer, 1993). Neurons act as miniature electrical units, each having a resting potential difference of $^{-}70$ millivolts. This means that the internal surface of the membrane is negative relative to the external surface (Fischbach, 1992). In order to transmit, a neuron reverses it's potential for a fraction of a second. This action reverses the polarity of the neuron, which, in turn, creates an electrical impulse that travels down the axon, away from the cell body, and towards adjoining neurons.

One of the main theories regarding the generation of the EEG rhythm postulates that the summation of such neural impulses, or potentials, leads to the generation of the various waves which are observed in the EEG spectrum (Speckman & Elger, 1993).

The implication of the above theory is, "that an event must occur which causes a change in polarization of the cellular membrane." (Graap, 1994). Extrapolating even further, it can be hypothesized that EEG readings are "snapshots" of neural activity. In other words, as the "output" of the living brain changes, so should the EEG pattern change to represent this "output". This change in EEG pattern has in fact been reported by several researchers (Mann, et al., 1992; Holcomb, Ackerman, & Dykman, 1986; Lubar, 1985; Satterfield & Schell, 1984; John et al, 1983; Fuller, 1977) during various cognitive tasks and during resting conditions.

WAVES PRESENT IN THE EEG PATTERN

There are four primary wave rhythms which are associated with the human EEG . These are: delta (0-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), and beta (between 12 Hz and 24 Hz) (Graap et al., 1994). Alpha was the first of the waves to be discovered and is known to be associated with the visual processing system (Ulrich, 1990; Nuñez, 1981). Beta and theta were the next two waves to be discovered and, in studies of attention, they are most often associated with fast and slow wave activity, respectively. Several researchers have reported that individuals diagnosed as ADD or ADHD typically exhibit theta/beta ratios that are statistically larger than those of normal individuals (Janzen et al., 1994; Janzen, 1992, Mann et al., 1991, Lubar et al. 1991, Lubar et al. 1985).

THE USE OF EEG PATTERNS IN STUDIES OF ATTENTION

An early study, which used clinical EEG as a diagnostic tool, was conducted by Grünewald-Zubergier & Rasche (1975) . They set out to study the neural arousal levels of hyperactive children (with attention deficit) and normal controls. Their goal was to determine whether or not the "deficit in attention" exhibited by their experimental group (children with ADHD), would be significantly represented in the EEG record.

Grünewald-Zubergier & Rasche (1975) began with a sample of 41 male subjects from the same school district. The median age for the boys was 12.2 years (quartile width = 1.1) and the median IQ was 95 (quartile width = 9.5), as determined by the WISC. Two experimental groups, matched according to age & IQ, were formed: (1) motor restless (ADHD), and (2) quiet children. EEG readings were recorded for each child while he was at rest (eyes closed and eyes open), as well as during a reaction time (RT) experiment, where the child was required to respond to a visual stimulus.

Grünewald-Zubergier & Rasche (1975) discovered that EEG readings clearly indicated that hyperactive children have "less-aroused" brains than non-hyperactive children. They reported that the hyperactive children exhibited significantly ($p<0.05$)) higher magnitudes of alpha (defined here as 8-14 Hz) and significantly lower magnitudes of beta (defined here as 14-22 Hz) waves. Also, they discovered that reaction times for the hyperactive children were significantly ($p<0.05$) slower than those for the non-hyperactive children.

The research of Grünewald-Zubergier & Rasche (1975) helped establish the theory that children with attention deficits (in this case, hyperactivity as well) had significantly different EEG patterns than normal children.

Recent studies (Janzen et al., 1994; Mann et al., 1992; Lubar et al. , 1985) have reported similar findings; that significant differences, in terms of EEG patterns, exist between ADD [with and without hyperkinesis (ADHD)] children and normal controls.

Lubar et al. (1985) compared the EEG patterns of 69 learning disabled (LD) children and 34 normal controls. All children with LD were diagnosed as having attention deficit. EEG readings were recorded while children performed the following: (1) sitting quietly, eyes open, (2) reading, (3) math, and (4) puzzle assembly. The readings were then analyzed using multivariate analysis to determine whether or not significant differences existed between the two groups of children.

Analysis of the data revealed that differences in EEG patterns (i.e. relative magnitudes of the different waves) between the two groups of children were indeed significant. Lubar et al. (1985) found that LD children exhibited (1) higher levels of Theta (4-8 Hz), (2) higher levels of Alpha (8-12 Hz), (3) increased muscle activity during all tasks (i.e. higher EMG: 24-32 Hz) , and (4) lower Beta (12-16 Hz) levels. According to Lubar et al. (1985) 97% of all LD children in this study were correctly diagnosed using EEG comparisons. However, Lubar et al. (1985) do qualify this claim by stating that their predictions were based upon comparisons between the children on the different measures, and not based on absolute magnitudes.

Lubar et al. (1985) also report that the differential effects between LD and normal controls were magnified as the children performed a cognitive task, such as reading. Under this "taxing" situation the normal children were reported to have an increase in beta activity, while maintaining relatively low theta levels. In contrast, the LD group were reported to have an increase in theta levels (with respect to baseline measures) without any significant increase in beta levels.

A closely related study was conducted by Mann et al. (1992). In this study, comparisons of on-task EEG were made between 25 ADHD and 27 normal children. All children were male and right-handed, with a mean age of 10.61 (SD = 1.0) for the ADHD sample, and 10.53 (SD = 1.1) for the normal controls. Mean IQ, as assessed by WISC-R full scale scores, was 102.5 (SD = 11.4) for the ADHD children and 107.0 (SD = 9.3) for the normal controls. EEG was collected during three conditions: baseline (eyes-open), reading, and drawing.

Significant differences were found to exist between children with attention deficits and those without. ADHD children exhibited significantly more theta activity and significantly less beta activity than normal controls. Also, ADHD children were reported to exhibit more frontal theta and lower frontal and temporal beta than normal controls. Like Lubar et al. (1985), Mann et al. (1992) reported that differences between ADHD and normal children were enhanced when the children were asked to perform a cognitive task: drawing, in this case. Mann, et al. (1992) reported that 80% of the ADHD children and 74% of the normal controls were correctly predicted using the relative differences in the EEG record alone.

Another study, by Janzen, Graap, Stephanson, Marshall, and Fitzsimmons (1994), attempted to test these earlier findings by conducting a replication study. In their study, Janzen et al. (1994) recorded the EEG rhythms of eight ADD children and eight normal controls. Comparisons were then made between the two groups in terms of relative amounts of EEG. The results in large part confirmed what had been reported in the previous studies. Janzen et al. (1994) found significant differences between ADD and normal controls in terms of average amplitudes of theta. However, unlike Mann et al. (1992) and Lubar et al. (1985), no significant differences were found to exist between ADD and normal children in terms of average beta amplitudes.

The aforementioned EEG studies, as well as other similar studies (Holcomb et al., 1986; Satterfield & Schell, 1984; John et al., 1983; Fuller, 1977), suggest that certain EEG parameters, such as alpha, theta, and perhaps beta, are associated with the presence or absence of attention, or attending behavior. In each study, children who were diagnosed as having a deficit in attention were also found to have significantly different EEG patterns than normal controls. Based on such findings, proponents of EEG analysis contend that comparisons between individual EEG patterns are a powerful means of determining relative attention (Lubar, 1991).

Another notable study was conducted by Matsuura et al. (1993). In this study, the goal was to determine whether significant differences in EEG band magnitudes existed between deviant children, hyperactive children (ADHD) and normal controls from three different nationalities: Korean, Chinese, and Japanese.

Matsuura et al. (1993) obtained samples of deviant, normal, and ADHD children from each of the three countries, matching for age and gender. For their assessment of deviant behavior, they administered (and scored) Rutter's questionnaires (Rutter, et al., 1970) to each of the subjects. However, the screening of subjects for the presence of ADHD was diagnosed in Psychiatric clinics in each of the three respective countries and not by the researchers themselves. The breakdown of the groups, as reported by Matsuura et al. (1993), was as follows:

| | | | |
|---|---|---|---|
| Deviant: | China (n = 39) | Japan (n = 27) | Korea (n = 87) |
| ADHD: | China (n = 41) | Japan (n = 27) | Korea (n = 87) |
| Normal: | China (n = 27) | Japan (n = 30) | Korea (n = 26) |

Eyes-open EEG was then recorded using the international 10-20 electrode system, developed by Jasper (1958) (see Appendix A for an illustration of the International 10/20 System). The four EEG bands which were considered were; theta, delta, alpha, and beta.

Matsuura et al. (1993) found that ADHD children exhibited higher amplitudes of alpha and theta, and had lower percentage time of delta than the normal and deviant groups. Also, children in the ADHD category produced significantly lower magnitudes of beta compared to the other two groups. The researchers concluded that ADHD was likely due to a biological dysfunction which was expressed as significantly different EEG patterns. However, Matsuura et al. (1993) found no significant differences between the EEG patterns of deviant children and normal controls. Therefore, they concluded that, unlike ADHD, deviant behavior is most likely due to psycho-social factors, rather than a biological dysfunction.

The work of Matsuura et al. (1993) has provided additional evidence to substantiate the use of EEG analysis as a means of discriminating between children with and without attention deficit. This study is [illegible] in that it provides evidence that EEG differences between [illegible] normal children are not culturally-based, but indeed biological in origin. If this is indeed the case, it provides additional evidence in support of the using EEG analysis as a diagnostic tool. As well, the findings of Matsuura et al. (1993) strengthen the theory which postulates that ADD and ADHD are due to a biological dysfunction and not social maladjustment.

## Stability of EEG Over Time

According to several studies (Graap et al., 1994; Burgess & Gruzelier, 1993; Fein et al. 1983; Gevins et al., 1979), EEG seems to be reasonably stable over time. This stability is represented by test-retest reliability coefficients reported in the literature which vary from approximately 0.75 to 0.90. As well, the nine interior sites (which will be the focus of this study) seem to be the most stable, having the highest reported coefficients of reliability (Graap et al., 1994).

# Test of Variables of Attention (T.O.V.A.™)

## Basis of the T.O.V.A.™

The theory behind the T.O.V.A.™ stems from research in the areas of vigilance and attention deficit. Studies in these areas have reported that children with attention deficits (i.e. ADD or ADHD) generally exhibit poor performance on tasks requiring either sustained or selective attention (Klorman, Salzman, Pass, Borgstedt, & Dainer, 1979; Werry & Aman, 1975; Sykes, Douglas, & Morgenstern, 1972; Sykes, Douglas, Weiss, & Minde, 1971).

By reviewing the relevant studies done in the area, Yellin (1980) proposed that researchers use a standard visual stimulus as a discriminant variable to test for attention. Based on tests of vigilance, he hypothesized that individuals with attention deficits would perform poorly on a discriminant stimulus test as compared to individuals diagnosed as having no attention deficit.

These tests of vigilance eventually evolved into a variety of continuous performance tests (CPTs). The T.O.V.A.™ is one example of a CPT. Simply, a CPT is a test which requires an individual discriminate between a target and a non-target by pressing or not pressing a key. Commonly, errors of omission and commission, as well as response time and response time variation are the outcome variables which are used to assess the individual's performance.

Halperin et al. (1988) investigated the use of CPTs as a means of differential assessment of attention and impulsivity in children. They found that errors of commission could be broken into parts to give even more meaningful parameters. This study suggested that impulsivity is most closely related to responses given before the presentation of the stimulus. According to Halperin et al. (1988), these anticipatory responses (AR) were significant indicators of impulsivity. To confirm this hypothesis, Halperin et al. (1988) computed correlation coefficients between anticipatory responses other measures of impulsivity, such as the

Connors Teacher's Questionnaire (CTQ). They reported that all correlation coefficients between AR and the CTQ were significant to the 0.01 level. This finding provided support for their hypothesis that anticipatory errors were good indicators of impulsivity.

Werry et al. (1987) used a CPT to compare children with attention deficit disorder with hyperactivity (ADHD), anxiety disorder, conduct disorder (CD), and normal controls. Their findings indicated that ADHD children exhibited more errors of omission than the normal controls, and that both the CD and ADHD groups made significantly more errors of commission than the normal controls.

Other studies (Waldman, 1990; Chee, 1989; Nuechterlein, 1983) have reported similar results. Generally, studies in the literature report that significant differences exist between ADD, ADHD, and normal controls in terms of the percentage of omission errors committed, percentage of commission errors committed and the mean response time variation. Reaction time, however, is not mentioned in the literature as being a significant indicator of attention or impulsivity.

Research Associated With the T.O.V.A.™

The T.O.V.A.™ was developed by researchers at the University of Minnesota as a means of measuring individual attention. In many ways, the T.O.V.A.™ is similar to a computer video game. The instrumentation consists of an IBM microcomputer, T.O.V.A.™ software, and a micro switch (i.e. hand-held button).

The T.O.V.A.™, itself, is a 22.5 minute objective, standardized, visual continuous performance test (CPT) of attention and impulsivity. It is a non-language based computerized test, requiring no right-left discrimination and has negligible practice effects (Greenberg & Crosby, 1992). The developers indicate that the T.O.V.A.™ was intentionally made long in order to assess attention during low arousal situations, as well.

As with other CPTs, the T.O.V.A.™ requires the subject to respond differentially to a cue (a square in this case), which is displayed on a computer screen for an interval of 100 milliseconds. If the square (cue) is presented at the top of the screen, the individual is required to respond, whereas if the square is presented at the bottom of the screen, the individual is required not to respond.

The T.O.V.A.™ measures four parameters: (a) errors of omission (%EO), where the subject has failed to respond to the appropriate cue; (b) errors of commission (%EC), where the subject has responded to a non-cue; (c) mean correct response time (RT), which is the average amount of time it took the subject to respond (i.e. average time between target display and subject response); (d) variance in response time (RTV), which indicates the variability of response time (Greenberg & Crosby, 1992).

Errors of omission (%EO) are used to determine relative attention, whereas errors of commission (EC) are used to determine relative impulsivity.

Studies Using the T.O.V.A.™ as a Measure of Attention

Greenberg and Crosby (1992) examined T.O.V.A.™ results of 73 children clinically diagnosed as having ADHD. For normal controls, Greenberg & Crosby (1992) used T.O.V.A.™ results from a sample of 775 children who had been tested in a previous study. The goal of their study was to assess the diagnostic effectiveness of the T.O.V.A.™ as a discriminant measure of attention. Results of this study were not very conclusive, indicating that the T.O.V.A.™ was effective to only a 0.611 - 0.8 level of sensitivity.

In a more comprehensive study, Greenberg and Waldman (1992) compared children with ADHD, ADD, and normal controls, in terms of their performance on the T.O.V.A.™. Results of this study indicated significant differences between the three groups. The ADHD and ADD groups made more omission errors and had greater reaction time variability than the normal controls. The ADHD group also exhibited more errors of commission and anticipatory errors than the other two groups. Although the ADD group made more errors of commission than the normal group, they did not make significantly more anticipatory errors. These results suggest that the T.O.V.A.™ is able to discriminate between ADD, ADHD, and normal children on the basis of differential performance on the various parameters.

The T.O.V.A.™ has also been used medically, to determine stimulant dosages. Raymond et al. (1993) used the T.O.V.A.™ to determine optimum dosage of methylphenidate (MPH – or Ritalin) for children with ADD. The assumption was made that children on MPH should perform better on measures of attention (such as the T.O.V.A.™) than children who were not on the drug. This assumption was based on the fact that MPH was an effectively proven treatment for children with ADD.

Children were administered MPH starting with 5 mg and increasing by 5 mg dosages every two weeks until a maximum of one milligram per kilogram of body weight was reached, or side effects occurred. Medication was administered twice daily, morning and afternoon. A baseline reading of the T.O.V.A.™ was taken, then subjects were re-tested every two weeks.

The results of the study revealed a linear relationship between increased dosage level and increased performance on the T.O.V.A.™ to an optimum of 0.54 mg/Kg. The optimum dosage range was reported to be between 0.32 and 0.62 mg/Kg. The researchers also noted that practice effect for the T.O.V.A.™ was negligible since the T.O.V.A.™ task requires constant attending.

This study showed that optimal dosages of MPH for children with ADD may be determined using the T.O.V.A.™. These results suggest that a high correlation exists between performance on the T.O.V.A.™ and relative attention and impulsivity.

## STUDIES EMPLOYING BOTH CPTs AND EEG ANALYSIS

Studies which employ both CPTs and EEG analysis deal mainly with the phenomenon of alpha-blocking, otherwise known as event-related desynchronization (ERD).

One example of such a study was conducted by Dujardin et al. (1993). In this study an attempt was made to determine what effect the degree of attention (i.e. high attention or low attention) would have on the magnitude of ERD (i.e. the magnitude of alpha).

For their study, Dujardin et al. (1993) selected 10 right-handed subjects between the ages of 18 and 21. Subjects were first required to learn a list of 12 words (i.e. memorize them). Then, they were asked to differentiate between the learned words and certain distractors as they were presented on a computer screen. Subjects, using a joystick in their right hand, either moved the joystick to the right for true (i.e. learned word), or to the left for false (i.e. distractor). There were two conditions present: high attention (distractors close to target) and low attention (distractors far from target). Task performance was evaluated using three variables: percent correct responses (%CR), percent false recognitions (%FR), and mean reaction times (RT).

In the procedure employed by Dujardin et al. (1993), EEG was recorded three seconds before and three seconds after stimulus presentation. A source derivation was obtained by using signals from 5 different electrodes; a source site surrounded by 4 closest electrodes (at right angles to the source site). The source sites used in the study were: C3, CZ, C4, P3, PZ, and P4. Percent ERD (%ERD) was obtained using the following formula:

$$(P - R) \times 100\%$$

where,

P = obtained power, and
R = reference power value.

It should be noted that Dujardin et al. (1993) recorded the EEG patterns of their subjects using the international 10/20 system, and digitized at a rate of 64 samples/second.

Dujardin et al. (1993) found significant differences existed between resting neural activity and attending neural activity in terms of %ERD. %ERD was significantly more pronounced in the high attention than in the low attention situation, although it was present in both. The researchers also reported that the phenomenon of %ERD lasted for approximately 1 second. Onset of %ERD (i.e. decrease in alpha) was found to occur earlier (approximately 0.5 seconds after stimulus presentation) in the high attention situation, than in the low attention situation (approximately 0.8 seconds after stimulus presentation). As well, the magnitude of %ERD in the high attention situation was found to be significantly greater than in the low attention situation ($p<0.001$).

Dujardin et al. (1993) reported that performance was dependent upon the degree of attention expressed in the task. The high attention situation produced better results than the low attention situation. The percentage of correct responses was found to be significantly greater in the high attention situation ($p < 0.05$). On the basis of their findings, Dujardin et al. (1993) concluded that the degree of ERD expressed (i.e. %ERD) is directly related to the amount of attention exhibited by an individual.

Other similar studies have been conducted in the area of %ERD research and have produced results consistent with those reported by Dujardin et al. (1993). For example, Klimesch et al. (1990) found that %ERD increased during a long term memory task. This study suggested that %ERD was related to internal as well as external attending.

As well, Pfurtscheller et al. (1989) showed that %ERD increases when an individual is planning or performing a voluntary movement. This work suggests that %ERD is also related to kinesthetic attending.

Sergeant et al. (1987), in a similar study, found that %ERD increases as subjects performed a sensory discrimination task. They reported that %ERD was directly related to the degree of sensory attending.

In fact, the bulk of the research conducted on alpha and attention, reports that as an individual's level of attenuation increases, the level of alpha decreases (as measured by an increase in %ERD). In other words, the degree to which someone is attending is correlated to their average alpha production.

## Statement of Research

EEG readings and performance on the T.O.V.A.™ are two of the current techniques used to assess relative individual attention. It is hypothesized that these two measures should be highly correlated to each other, since they purport to measure the same construct; attention. Therefore, the null hypothesis in this study will be Ho: $\rho = 0$ (where $\rho$ is the Pearson product moment correlation between EEG parameters and T.O.V.A.™ parameters).

## Research Questions

The primary question which this study will attempt to answer is whether EEG patterns (in terms of wave magnitudes) and T.O.V.A.™ results are significantly correlated. Specifically, this study will be focusing on the EEG parameters (waves) mentioned in the literature; Delta, Theta, Alpha, and Beta. However, in order to be comprehensive, nine bands in total will be examined (refer to table 2.1 for a list of the bands and band specifications which will be used in this study).

Pearson product moment correlation coefficients will be calculated between the average magnitudes of each of the nine EEG bands and the results on each of the four parameters; Errors of Omission (%EO), Errors of Commission (%EC), Response Time (RT), and Response Time Variability (RTV).

TABLE 2.1

Definition of Frequency Bands

| Band (Wave) Title | Start Frequency | End Frequency |
|---|---|---|
| Delta | 0.5 Hz | 4.0 Hz |
| Theta | 4.0 Hz | 8.0 Hz |
| Alpha | 8.0 Hz | 12.0 Hz |
| SMR | 12.0 Hz | 16.0 Hz |
| Beta1 | 16.0 Hz | 20.0 Hz |
| Beta2 | 20.0 Hz | 24.0 Hz |
| Beta_All | 12.0 Hz | 24.0 Hz |
| EMG | 24.0 Hz | 32.0 Hz |
| Total_EEG | 0.5 Hz | 32.0 Hz |

Note. There is no overlap of bandwidths with the Lexicor software (Lexicor, 1990).

The sites which will be of primary concern in this study will be the nine interior sites of C3, C4, CZ, FZ, O1, O2, P3, P4, and PZ; placed according to the International 10/20 System (Appendix A). Correlation tables between EEG bands and T.O.V.A.™ parameters will be computed for each of these nine sites width of interest (refer to table 2.2 for an example of the layout of these tables).

Using a design such as that illustrated in table 2.2 will allow inferences to be made not only about the type and degree of the relationship between the magnitudes of the various EEG bands and those of the four T.O.V.A.™ parameters, but also the nature of this relationship across sites.

TABLE 2.2

Sample Correlation Table (example site C3)

| Band Name | Errors of Omission | Errors of Commission | Response Time | Response Time Variability |
|---|---|---|---|---|
| **Delta** | ρ | ρ | ρ | ρ |
| **Theta** | ρ | ρ | ρ | ρ |
| **Alpha** | ρ | ρ | ρ | ρ |
| **SMR** | ρ | ρ | ρ | ρ |
| **Beta1** | ρ | ρ | ρ | ρ |
| **Beta2** | ρ | ρ | ρ | ρ |
| **Beta_All** | ρ | ρ | ρ | ρ |
| **EMG** | ρ | ρ | ρ | ρ |
| **Total_EEG** | ρ | ρ | ρ | ρ |

ρ = Pearson product moment correlation

This study also intends to investigate the utility of EEG bands, in terms of their ability (if any) to predict performance on T.O.V.A.™ parameters. To this effect, a multiple regression analysis will be used in order to determine whether or not any predictive equations exist.

# CHAPTER 3

# METHODS AND PROCEDURES

## INITIAL SELECTION OF THE SAMPLE

It is only appropriate that this chapter begins by acknowledging the efforts of Graap et al. (1994) who originally selected the sample of children which were used in the following study. Special consideration goes to Troy Janzen of the University of Alberta who was instrumental in developing the procedural protocol used in this investigation. In fact, this study was conducted as an addition to a follow-up study which was already being conducted by Troy Janzen of the University of Alberta.

In the original design, Graap et al. (1994) set out to obtain a sample of twenty five, normal-functioning, right-handed males for their sample. To this effect, they approached a local elementary school and twenty five candidates were selected. The boys selected were then provided with a comprehensive orientation session regarding the intended study. During the orientation, the boys were made familiar with the various materials that were going to be used in the study, such as the cap, the sensors, the electrogel, the computer and the computer software. Following the orientation session, each of the twenty five boys was provided with a detailed information package to give to his parents. This package contained a description of the study, an informed consent form and a history sheet: the latter two were to be completed by the parents or guardians of the child.

Out of the twenty five boys originally selected, Graap et al. (1994) reported that only fourteen volunteered to take part in the study. Therefore, Graap et al. (1994) expanded the criteria to include left-handed males as well. By so doing, an additional three participants were recruited, bringing the total sample size to 17. It is this same sample of seventeen boys (14 right-handed and 3 left-handed) which was used in the study which is the focus of this thesis.

## INSTRUMENTS

### LEXICOR NEUROSEARCH-24 (NRS-24)

An NRS-24 machine (Lexicor Medical Technology, Inc., Boulder, CO) was used to record the EEG pattern of each subject in the study.

### ELECTROCAP

In order to receive brainwave information from the subjects, an electrocap was used, which was connected to the NRS-24. This device consists of a cap in which are positioned twenty electrodes according to the international 10-20 system (refer to Appendix A for an illustration of the International 10/20 System).

The NRS-24 collects EEG data from 20 locations on the scalp via the electrocap. This information is then processed using the Lexicor Biolex software.

Settings for the NRS-24 were as follows: a Sampling Rate of 128 samples per second; a Gain of 32000; High Pass Filter of 0.5 Hz; Low Pass Filter of 32 Hz.

Several studies have been conducted on the reliability of EEG readings over time. For example, Fein, et. al (1983) recorded the EEG patterns of normal and dyslexic children in a five hour test-retest situation. They reported their results in the form of inter class correlation coefficients (ICC), which measure the proportion of total variance accounted for by inter-subject differences. For normal controls, Fein, et al. reported reliability coefficients ranging from 0.8 to the 0.9 depending upon the location of the sensor (i.e. site location). The reliability coefficients for the dyslexic children were slightly lower. The researchers speculated that these results may be attributed to the presence of more artifact (i.e. contamination of data) in the EEG data of the dyslexic group.

Graap et al. (in press), using the NeuroSearch 24, conducted an eight day test-retest study of the 17 normal elementary school children described above. Using Spearman rank order correlation coefficients, reliability coefficients were found to vary from a low of 0.35 to 0.96, depending on sensor location and the task in which the children were engaged. Overall, Graap et al. (in press) found EEG readings in the seven interior sites of C3, C4, CZ, FZ, P3, P4, and PZ to be reasonably stable over an eight day period.

TEST OF VARIABLES OF ATTENTION (T.O.V.A.™)

The instrumentation for this measure consists of a hand-held switch connected to an IBM 486 DX computer and the T.O.V.A.™ software program.

As described in chapter 2, the subject is required to respond differentially to a visual cue presented on the computer screen for an interval of 100 milliseconds (0.1 seconds). This cue consists of a square which, if presented at the top of the screen, the subject is to press the switch and, if presented at the bottom of the screen, the subject is not to press the switch. The computer then records the four T.O.V.A.™ parameters of response time, response time variation, percent errors of omission, and percent errors of commission.

The T.O.V.A.™ has been standardized on a population of approximately 2000 individuals ranging in age from 4 to over 80 years of age. However, being a new instrument, there are no studies pertaining to the reliability of the T.O.V.A.™ in the literature, nor do the developers themselves report any reliability data.

DATA COLLECTION - ON SITE

All data collection was conducted at the school in which the boys were enrolled. The equipment, which consisted of two computers, the NRS-24, and the various wires and switches, was set-up in a workroom within the school. All recordings were conducted during regular school hours, each boy being taken out of class and escorted to the "study room". Each subject was once again familiarized with the equipment and the procedures, with the addition of the second computer which was to be used for the T.O.V.A.™.

ARTIFACT TRAINING PRIOR TO EEG RECORDING

Prior to recording EEG data, each of the boys was shown his EEG pattern on the computer screen. He was then instructed to create common artifacts, such as eye movements, jaw-clenching, temporal tension, and forehead tension. After seeing what these artifacts looked like, the child was then directed to try to limit those movements which would lead to such artifacts. All the boys, being already familiar with the procedure, complied quite readily with the instructions. However, during some recording sessions pauses were made and some of the boys were reminded about the creation of artifact. By so doing, the researchers believe that cleaner data was obtained.

EEG RECORDING AND ADMINISTRATION OF THE T.O.V.A.™

As stated earlier, this current study was conducted alongside a follow-up of the study conducted by Graap et al. (1994). Therefore, before the T.O.V.A.™ was administered and an "on- T.O.V.A.™" EEG recorded, the subjects first performed a number of other tasks. These pre-T.O.V.A.™ tasks took approximately one hour to complete. The recording of the "on- T.O.V.A.™" EEG data, as well as the administration of the T.O.V.A.™ were carried-out after these other tasks had been completed.

For the actual test conditions, each boy was seated in a comfortable chair, approximately two feet from the computer screen. For added comfort, a pillow and a foot rest were also made available if the boy wished to use one. The subject was then briefly oriented to the T.O.V.A.™, including a two minute practice session. The electrocap, having been previously fitted to the child's head, was then checked for the level of the impedances. The electrocap was adjusted until all impedances were below 5 ohms. It should be noted that all impedance and microvolt readings were ear-referenced.

Once the above preliminaries were complete, each subject was administered the T.O.V.A.™ and his EEG pattern was simultaneously recorded. The T.O.V.A.™ and EEG were run simultaneously in order that inferences regarding "on- T.O.V.A.™" EEG patterns could be made later in the analysis. Due to the fact that subjects had already been wearing the electrocap for over one hour, EEG readings were only recorded for the first ten minutes of the T.O.V.A.™ task. This was done in order to keep to a minimum the amount of discomfort, if any, which was experienced by the children. Usually, the electrocap gets quite itchy after a period of time. For the purposes of testing the relationship between T.O.V.A.™ parameters and EEG readings, ten minutes of "on- T.O.V.A.™" EEG recording was deemed more than sufficient. Each child, however, did complete the full 22 minute T.O.V.A.™.

## DATA ANALYSIS PROCEDURES

Originally, the EEG data collected was divided into the following three categories (in order to mimic the T.O.V.A.™, which is divided into four quarters, each of which is approximately five minutes in length):

(1) First five minutes "on- T.O.V.A.™"

(2) Second five minutes "on- T.O.V.A.™"

(3) Full ten minutes "on- T.O.V.A.™"

The original intention was to compute correlation coefficients between the first five minutes of the T.O.V.A.™ and the first five minutes of EEG recording, then repeating this procedure using the second five minutes and the full ten minutes. However, since (1) and (2) were actually extrapolations of (3), and in order to pare-down the data to a workable size, only (3) was used for analysis purposes in this thesis. Therefore, the relationship between the first ten minutes of "on- T.O.V.A.™" EEG and T.O.V.A.™ scores over those same ten minutes became the focus of the analysis of this thesis.

# CHAPTER 4

# RESULTS

## SAMPLE

### SIZE AND AGE

This study originally began with a sample size of 17 subjects. However, due to technical problems, the data of one of the subjects (ID#=2) was not usable. Therefore, a sample size of 16 was used for the remainder of this study and the analysis.

The average age of the sample was 138 months (11 years, and 6 months). The ages ranged from 126 to 148 months. EEG patterns for individuals in this particular age range have been shown to be reasonably stable over time ( Graap, 1994; Fein, et al., 1984).

### RELEVANT PSYCHOMETRIC RESULTS OBTAINED IN PREVIOUS STUDY

In order to screen out any abnormal subjects (in terms of ADD & ADHD), Graap (1994) administered the Swanson Teacher Questionnaire (SNAP ) to each of the 17 subjects in the sample. The criteria which was chosen to differentiate between normal and abnormal was two standard deviations above the published norms for the SNAP. Graap (1994) reported that only one subject met this criteria, and even then, in only one of the four subtests. Since this subject was deviant on only the one subtest, and no further evidence (i.e. no abnormal problems at school, home, or with his peer groups) was found to support dropping him from the study, Graap (1994) retained him in the previous study. This subject was once again retained for the purposes of this study.

Other than the above, no further psychometric measures were administered to the sample group.

## ARTIFACTING OF COLLECTED EEG DATA

The quality of the EEG pattern is affected by several factors, which are referred to as artifact. Common sources of artifact include extreme eye movement, muscle tension, and excessive movement. The presence of artifact in any particular epoch (2 seconds of recorded EEG) renders that epoch unusable. In order to obtain the most reliable data possible, the EEG record of each subject was visually inspected, epoch by epoch. Any epochs which were not of extremely high quality (i.e. free from any type of artifact) were discarded. All artifacting (i.e. removal of tainted epochs) in this study was conducted immediately after each session. On average, 87 epochs were included per subject ($Std.Dev_{pooled}$=28 epochs).

## RAW DATA RESULTS OF THE T.O.V.A.™ AND EEG READINGS

Actual raw number data for the T.O.V.A.™ parameters and average EEG band magnitudes (and standard deviations) are presented in Appendices B and C, respectively. In Appendices D and E, T.O.V.A.™ and EEG data are presented in the form of box and whisker plots (boxplots). Boxplots were chosen to represent the data in that they facilitate the identification of any possible outliers or extreme cases. Although a thorough analysis of all outliers and extremes is not within this scope of this thesis, it will be the subject of a forthcoming paper. The boxplots are included in this thesis for purposes of reference.

CORRELATIONS BETWEEN EEG BANDS AND T.O.V.A.™ PARAMETERS

For each of the nine channels (sites), Pearson product moment correlation coefficients (ρ) were computed between the average magnitude of each EEG band (refer to table 2.1 for specification of bands and bandwidths) and the scores obtained on each of the four T.O.V.A.™ parameters. A directional (i.e. two-tailed) statistical test was used to determine the significance of the obtained correlation coefficients. The hypothesis being tested was that the correlation coefficients between each of the four T.O.V.A.™ parameters and average magnitudes of each of the nine EEG bands would be equal to zero (i.e. $H_o$: $\rho_{T.O.V.A.^{TM}/EEG} = 0$). With a sample size (n) of 16 and a two-tailed alpha level of 0.05, the critical value for "ρ" was determined to be **0.43** (adapted from Glass & Hopkins, 1984, p.549). However, due to the fact that the sample group was extremely homogeneous (only normal-range boys), the critical value of ρ was reduced to **0.40**. This was done in an attempt to maximize inclusion of any significant correlation coefficients which may have been present in the data.

A great many correlation coefficients were computed for this study. Coefficients between all four T.O.V.A.™ parameters and the magnitudes of each of nine EEG bands across nine sites were computed (i.e. 4 x 9 x 9 = 324 correlation coefficients). Therefore, for the purposes of clarity only significant correlation coefficients were presented in this chapter. For complete tables containing all of the above-mentioned correlation coefficients, please refer to Appendix F.

SIGNIFICANT CORRELATION COEFFICIENTS BY SITE

TABLE 4.1

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE C3

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Delta** | **-0.53**$^{2}$ | **-0.65**$^{4}$ | | **-0.52**$^{2}$ |
| **Theta** | | **-0.57**$^{2}$ | | |

Notes. 1: $p < 0.05$ 2: $p < 0.025$ 3: $p < 0.01$ 4: $p < 0.005$ 5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

For site C3, T.O.V.A.™ parameters were found to correlate with two EEG bands: delta (D) and theta (TH) (see table 4.1). Strong negative relationships were found to exist between delta and the three T.O.V.A.™ parameters of percent errors of omission (%EO), percent errors or commission (%EC), and reaction time variability (RTV). This result indicated that high average C3 delta was related to better performance on the T.O.V.A.™, in terms of lower %EO, %EC, and RTV.

As well, a strong negative relationship found to exist between theta and %EC at site C3. This relationship indicated that the higher the average C3 theta magnitude, the lower the %EC. It should also be noted that all four of the above-mentioned correlation coefficients were significant to the 98'th level of confidence or better (i.e. $p<0.025$).

TABLE 4.2

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE C4

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| Delta | -0.40 | -0.46[1] | | -0.40 |
| Theta | | -0.49[2] | | |

Notes. 1: $p < 0.05$ 2: $p < 0.025$ 3: $p < 0.01$ 4: $p < 0.005$ 5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

Of note in table 4.2 is the presence of the same four significant correlation coefficients which were found at site C3: D vs. %EO, D vs. %EC, D vs. RTV, and TH vs. %EC. However, the correlation coefficients at this site (C4) appeared to be smaller than those observed at site C3. Only two of the correlation coefficients at site C4 were more significant than the $p<0.05$ level: TH vs. %EC ($p<0.025$) and D vs. %EC ($p<0.05$).

It was expected that sites C3 and C4 would yield similar correlational results. This assumption was based on the fact that these two sites are positioned equidistant from the midline of the cerebrum, but on opposite sides. However, as mentioned above, it appeared that there were differences in the magnitudes of the observed correlation coefficients at these two sites. Therefore, the hypothesis that the correlation coefficients were equal (i.e. $\rho_{C3} = \rho_{C4}$) was tested. Using a z-critical value of 1.96 (i.e. 95% level of confidence) the null hypothesis was not rejected. Hence, it was concluded that the observed differences in the magnitudes of the correlation coefficients between sites C3 and C4 was due to chance alone.

TABLE 4.3

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE CZ

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Delta** | **$-0.55^{2}$** | **$-0.57^{2}$** | | **$-0.44^{1}$** |
| **Theta** | **-0.40** | **$-0.56^{2}$** | | |

Notes. 1: $p < 0.05$ 2: $p < 0.025$ 3: $p < 0.01$ 4: $p < 0.005$ 5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

Site CZ was one of the sites of interest, being that it was located in the "geographic" center of the cranium. Again, delta at this site was found to correlate rather strongly with %EO and %EC, and moderately with RTV. Also, as before, the TH vs. %EC relationship was again present at site CZ.

A modest relationship which was not present in the previously mentioned sites was the TH vs. %EO relationship. Although this was not found to be a very strong correlation, it was noted in case it proved to be part of a later pattern.

TABLE 4.4

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE FZ

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Delta** | **-0.63[4]** | **-0.54[2]** | | **-0.42** |
| **Theta** | | **-0.40** | | |
| **Alpha** | **0.42** | **0.46[1]** | | |

Notes. 1: $p < 0.05$   2: $p < 0.025$   3: $p < 0.01$   4: $p < 0.005$   5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

FZ was the only frontal region site which was used in this analysis. As before, the same four correlation coefficients were again present at site FZ. Unlike the previously discussed sites, however, positive correlation coefficients were found to exist between alpha (AL) and %EO and %EC at site FZ. This result indicated that as the average magnitude of alpha (at site FZ) increased, %EO and %EC also increased.

TABLE 4.5

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE O1

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Alpha** | **0.77[5]** | **0.69[4]** | | **0.71[4]** |
| **Beta1** | **0.48[2]** | **0.45[1]** | **-0.40** | |
| **Total_EEG** | **0.58[3]** | **0.47[1]** | | **0.41** |

Notes. 1: $p < 0.05$   2: $p < 0.025$   3: $p < 0.01$   4: $p < 0.005$   5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

Site O2 represented the greatest number of significant correlation coefficients between EEG bands and T.O.V.A.™ parameters. Of greatest interest are the extremely strong positive correlations between alpha and %EO ($p<0.001$), alpha and %EC ($p<0.005$), and between alpha and RTV ($p<0.005$). These coefficients indicated that as the average magnitude of O1 alpha increases, %EO and %EC also increased. As well, it can be deduced from the large, positive correlation coefficient between alpha and RTV, that those subjects who exhibited lower average alpha also exhibited less variability, in terms of their average reaction time.

Also apparent from table 4.5, are the moderately strong positive correlation coefficients between beta1 (B1) and %EO, and %EC. These correlations indicated that the higher the average B1 magnitude at site O1, the higher the %EO and %EC. As well, a modest negative correlation was found to exist between B1 and reaction time (RT), which indicated that the higher the average B1 magnitude at site O1, the shorter the average RT.

Positive correlations were also observed between total EEG (TEEG) and %EO, and %EC. These correlations indicated that as TEEG at site O1 increased, %EO and %EC also increased. It should be noted that the TEEG vs. T.O.V.A.™ relationship was found to be significant only at site O1.

One last notable finding from site O1 was the absence of the four strong correlation coefficients which were previously mentioned: D vs. %EO, D vs. %EC, D vs. RTV, and TH vs. %EC. In fact, significant correlations between delta or theta and any of the four T.O.V.A.™ parameters were found only in the frontal (FZ) and central (C3, C4, CZ) regions.

TABLE 4.6

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE O2

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Alpha** | **0.63[4]** | **0.56[2]** | | **0.66[4]** |
| **Beta2** | | | **-0.49[2]** | |
| **Total_EEG** | **0.41** | | | |

Notes. 1: $p < 0.05$ 2: $p < 0.025$ 3: $p < 0.01$ 4: $p < 0.005$ 5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

As previously explained with sites C3 and C4, sites O1 and O2 are also equidistant from the midline of the cranium but on opposite sides. Therefore, it was again expected that correlation coefficients for this site would be similar to those found at site O1. Once again, a z-test was applied to the observed differences. As with sites C3 and C4, no significant differences were found to exist between similar correlation coefficients at sites O1 and O2. Therefore, the observed difference in the magnitudes of similar correlation coefficients at sites O1 and O2 were accounted for by chance.

Of note at site O2 are the strong positive correlations which were found to exist between alpha and the three T.O.V.A.™ parameters of %EO,

%EC, and RTV, respectively. This indicated that lower occipital alpha production was strongly related to lower errors of omission and lower errors of commission, as well as more stable reaction time (in terms of variation).

Another very interesting finding was that, contrary to what was observed at site O1, site O2 contained no significant correlations between B1 and any of the T.O.V.A.™ parameters. In place of B1, however, a strong ($p<0.025$) negative correlation between beta2 (B2) and RT was observed. This result indicated that the higher the average B1 magnitude at site O2, the lower the RT. It could be that B1 is produced more predominantly in O1 and B2 is produced more predominantly in O2.

One last modest correlation to note from table 4.6, is that between TEEG and %EO. Although the magnitude of this correlation coefficient appears to be smaller than the same coefficient at site O1, statistically the difference is not significant (at the 95% level of confidence).

TABLE 4.7

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE P3

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Alpha** | **0.73[4]** | **0.70[4]** | | **0.73[4]** |

Notes. 1: $p < 0.05$ 2: $p < 0.025$ 3: $p < 0.01$ 4: $p < 0.005$ 5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

TABLE 4.8

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE P4

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Alpha** | **0.53²** | **0.42** | | **0.59³** |

Notes. 1: $p < 0.05$  2: $p < 0.025$  3: $p < 0.01$  4: $p < 0.005$  5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

At sites P3 and P4, represented by tables 4.7 and 4.8 respectively, alpha was the only band which was found to be significantly correlated to any of the T.O.V.A.™ parameters. As was observed at the occipital sites (O1 and O2), strong correlations between alpha and the T.O.V.A.™ parameters of %EO, %EC, and RTV appeared in the parietal (P3 and P4) region. These significant correlation coefficients indicated that the higher the average P3 and P4 alpha magnitude, the higher the %EO and %EC. In other words, the greater the average alpha in the parietal region, the higher the expected number of errors on the T.O.V.A.™.

TABLE 4.9

SIGNIFICANT CORRELATION COEFFICIENTS FOR SITE PZ

| | %EO | %EC | RT | RTV |
|---|---|---|---|---|
| **Alpha** | **0.53²** | **0.49²** | | **0.60³** |

Notes. 1: $p < 0.05$  2: $p < 0.025$  3: $p < 0.01$  4: $p < 0.005$  5: $p < 0.001$

%EO = Percent Errors of Omission committed.
%EC = Percent Errors of Commission committed.
RT = Reaction Time.
RTV = Reaction Time Variability.

In terms of the type and magnitudes of significant correlation coefficients, site PZ was found to be quite similar to sites P3 and P4. Again, alpha was found to correlate to %EO, %EC, and RTV. Of interest at site PZ, was the observation that the magnitudes of the PZ correlation coefficients of AL vs. %EO and AL vs. %EC were quite similar to the magnitudes of the same correlation coefficients at site P4. Although these differences were found to be non-significant statistically, they were mentioned as a point of speculation.

It should be noted here that the standard deviations of alpha at the occipital and parietal sites were also correlated to %EO, %EC, and RTV. This finding suggested that higher levels of alpha in these regions was most likely due to bursts in magnitude, and not a consistently high rate of alpha production.

## MULTIPLE REGRESSION ANALYSIS

Two multiple regression analyses were conducted in order to determine the degree to which the two T.O.V.A.™ parameters of percent errors of omission and percent errors of commission could be predicted from the average magnitudes of the various EEG bands (based on the sample of 16 normal boys). In each analysis, delta, theta, alpha, smr, beta1, and beta2 from each of the nine sites were used in the regression equations. A multiple stepwise regression procedure, using a criterion of 0.05, was then used to provide the best-fitting equation for each of the two models. For the purposes of this thesis, two indicators were used in order to determine the "fit" (i.e. how well the equation accounted for the sources of variation in the criterion) of each equation: the squared multiple correlation ($R^2$), and the standard error of prediction ($S_E$). The closer $R^2$ is to "1", the higher the degree of fit and the closer $S_E$ is to "0", the better the fit.

TESTING THE ASSUMPTIONS OF THE MULTIPLE REGRESSION EQUATION

Multiple regression is based on two basic assumptions: normality (i.e. normal distribution of observations) and homoscedasticity (uniform variance). There is also a third, related, condition which should be met if a multiple regression equation is to be generalized to other cases, and that is the condition of independence of errors. For the purposes of this thesis, all three of the above conditions were tested for each multiple regression equation. To test the condition of normality, the residuals from each of the two multiple regression equations were plotted on a normal probability graph. This procedure required that all residuals be distributed close to the observed vs. expected cumulative probability line (O/E-LINE) in order for the condition of normality to be met. It should be noted here that no distribution is perfectly normal and fluctuations of residuals around the O/E-LINE are inevitable (unless the equation perfectly fits the data – i.e. $R^2$=1 and $S_E$).

To test the assumption of homoscedasticity, another regression equation was computed, between the predicted standard residual (ZPRED) and the square of the observed standard residual [$(ZRESID)^2$]. This procedure required that the $R^2$ [$(RES)^2$] value for this regression equation be close to zero for the condition of homoscedasticity to be claimed (adapted from Newbold, 1988, pp. 576-580).

To test for independence of errors a Durbin-Watson (DW) statistic was computed for each multiple regression equation. In order to claim that the errors were independent, the observed DW was tested against the critical table value of 1.93. This value was based on sample size of 16, with four predictor variables in the equation (adapted from Newbold, 1988, pp. 581-588).

<u>PREDICTING ERRORS OF OMISSION FROM AVERAGE EEG BAND MAGNITUDES</u>

$$\%EO_P = 1.49A\_O1 - 1.16A\_O2 - 2.83D\_FZ + 1.07D\_PZ + 37.3 \quad \text{eq}^n\ 4.1$$

where,

$\%EO_P$ = predicted percent errors of omission
A_O1 = average alpha magnitude at site O1
A_O2 = average alpha magnitude at site O2
D_FZ = average delta magnitude at site FZ
D_PZ = average delta magnitude at site PZ.

The multiple R for equation 4.1 was computed to be 0.95, providing an $R^2$ value of 0.90. This $R^2$ value indicated a high degree of fit for model 4.1 (i.e. equation 4.1). The above model indicated that by using the average magnitudes the four EEG bands of A_O1, A_O2, D_FZ, and D_PZ, 90% of the variance in %EO was accounted for (i.e. predicted).

The $S_E$ for equation 4.1 was also found to be quite low, with a value of 3.5. This meant that when using equation 4.1 to predict %EO, the predicted value ($\%EO_P$) would be expected to be within 3.5% of the actual value ($\%EO_{OBSERVED}$), using a 68% confidence interval.

A most intriguing finding that was observed in equation 4.1 was that %EO varied as a function of higher O1 alpha and lower O2 alpha. This indicated that there may be hemispheric differentiation during a visual task, in terms of alpha production. This same phenomenon was also observed with delta (in equation 4.1). %EO was seen to vary negatively with FZ delta and positively with PZ delta. This finding indicated that differing magnitudes of delta in the frontal and parietal regions could account for some of the variance in the observed frequency of errors of omission.

An important note to make here is that, although this predictive relationship is extremely strong, it can only be applied to normal boys, aged 11 to 13; it cannot be generalized to the entire population. With this in mind, it may be concluded from equation 4.1, that %EO is a function of occipital (O1 & O2) alpha magnitude and midline (FZ & PZ) delta magnitude.

TESTING OF ASSUMPTIONS FOR EQUATION 4.1

Analyzing the normal probability graph for equation 4.1 (see Appendix G, figure G.1), the observations were seen to be distributed more or less around the O/E-LINE. Therefore, it was concluded that the underlying distribution, upon which equation 4.1 was based, was relatively normal.

For the assumption of homoscedasticity, a $(RES)^2$ value of 0.042 was observed. This extremely low value, indicated that the condition of homoscedasticity was met for equation 4.1.

In terms of the DW statistic, a value of 2.55 was computed for equation 4.1. Since this value was found to be significantly larger than the critical value of 1.93, it was concluded that the condition of independence of errors was met for equation 4.1.

PREDICTING ERRORS OF COMMISSION FROM AVERAGE EEG BAND MAGNITUDES

$$\%EC_P = {}^{-}1.34A\_C3 + 1.42A\_P3 - 0.56A\_P4 + 1.66B2\_O2 + 1.66 \quad \text{eq}^n\ 4.2$$

where,

$\%EC_P$ = predicted percent errors of commission
A_C3 = average alpha magnitude at site C3
A_P3 = average alpha magnitude at site P3
A_P4 = average alpha magnitude at site P4
B2_O2 = average beta2 magnitude at site O2.

The multiple R for equation 4.2 was observed to be 0.95, providing an $R^2$ value of 0.90. Again, this meant that model 4.2 fit the data extremely well, based upon the variables in the equation. The $S_E$ for equation 4.2 was also found to be very low: $S_E = 1.67$. Therefore, when using equation 4.2 to predict %EC, the predicted value ($\%EC_P$) would be expected to be within 1.67% of the actual value ($\%EC_{OBSERVED}$), using a confidence interval of 68%.

Also noted from equation 4.2 was the fact that %EC appears to be highly affiliated with average alpha magnitude, especially in the parietal region. Based on equation 4.2, %EC varies negatively as a function of C3 and P4 alpha, and positively as a function of P3 alpha and O2 beta. Speculating as before, it would appear that %EC is best explained as a function of parietal alpha, left/central alpha, and right/occipital beta2. Again, these findings were indicative of hemispheric differentiation.

It should be noted that the inferences made from equations 4.1 and 4.2 are based on the presence of all variables in the equations. Such inferences could not be made about the individual variables in the equations.

Testing of Assumptions for Equation 4.2

The distribution of residuals for equation 4.2 was observed to have a higher degree of normality than the distribution for equation 4.1 (see Appendix G, figure G.2). As can be seen from figure G.2, the observations for equation 4.2 are distributed quite close to the O/E-LINE. This indicated that the underlying distribution closely resembled a normal distribution.

Hence, it was determined that the assumption of normality was met for equation 4.2.

For the condition of homoscedasticity, a $(RES)^2$ value of <0.00001 was obtained. This value was found to be consistent with the high normality of this distribution. Based upon this result, it was concluded that the condition of homoscedasticity was met for equation 4.2.

The DW statistic for equation 4.2 was calculated to be 2.52. This value is well above the critical value of 1.93. Therefore, it was concluded that the condition of independence of errors was met for equation 4.2.

Both equation 4.1 and equation 4.2 satisfied all three conditions pertaining to multiple regression equations. Therefore, any inferences made using either of these two equations may be considered valid. Of course, this is providing that those inferences fall within the guidelines of those allowed by multiple regression theory.

Complete computations pertaining to the preceding multiple regression analyses are presented in appendix H.

# CHAPTER 5

## DISCUSSION AND CONCLUDING REMARKS

This study extended the knowledge in the area of EEG research by establishing that certain EEG bands are indeed related to the cognitive constructs of inattention and impulsivity. As well, evidence was found which indicated the existence of predictive relationships between these same EEG bands and cognitive constructs.

## RESULTS

In order to explain the results in the most concise and coherent fashion, they will be presented here by EEG band. As was the case in chapter four, only those bands which were significantly correlated to any of the T.O.V.A.™ parameters will be discussed in this chapter. Another point to note is that inferences made in this chapter are based upon the restricted population of normal (i.e. not ADD or ADHD) 11 to 13 year old boys in relation to a visual performance task. Generalizing these findings to other populations and/or other tasks would not be logical.

### ALPHA

There has been a great deal of research conducted in the area of cerebral alpha production, especially in the occipital region (i.e. sites O1 and O2). Early researchers (Mulholland & Evans, 1965; Lippold, 1973; and Nuñez, 1981) were convinced that the alpha rhythm was linked to eye-movement. However, later researchers (Dujardin et al., 1993; Klimesch et al., 1990; Pfurtscheller, 1989; Sergeant et al., 1987; Warren and Haueter, 1981; and Kinsbourne, 1973) discovered that the alpha rhythm was more a function of underlying cognitive processes, such as attention, vigilance, or alertness.

The most significant correlations observed in this study were those between the magnitude (and standard deviation) of alpha and the T.O.V.A.™ parameters of %EO, %EC and RTV, especially in the occipital (i.e. sites O1 and O2) and parietal (i.e. sites P3, P4, and PZ) regions. These results suggested that alpha magnitude was strongly related to relative attention and impulsivity (as measured by the T.O.V.A.™ parameters of %EO and %EC, respectively). Also, the fact that the standard deviations of alpha were also correlated to %EO, %EC and RTV, suggested that higher alpha levels were most likely due to bursts in alpha production.

As well, strong correlations were observed between alpha and RTV, which indicated that variation in reaction time was also related to alpha production. Several researchers (Waldman, 1990; Chee, 1989; Nuechterlein, 1983) have reported that these same three parameters (%EO, %EC, and RTV) on continuous performance tests (CPTs) significantly differentiate between children with attention deficit (ADD) and normal controls.

The claim of the early theorists, that the alpha rhythm was due to eye-movement, may be ruled out as a possible conflicting hypothesis in this study. This is due to the fact that eye-rolling (or eye-movement in general) is an easily recognized form of artifact and epochs containing such artifact were removed from the data pool. Therefore, it is highly unlikely that a significant number of "eye-movement-epochs" remained for each subject, to account for the extremely large correlation coefficients which were obtained. Hence, the hypothesis that the observed fluctuations in the magnitude of alpha were due to eye-movement is not a tenable one.

The results pertaining to alpha (i.e. alpha magnitude as a function of relative attention) are more consistent with the findings of contemporary research studies. Dujardin et al. (1993) reported that alpha production significantly decreased as the level of individual attention increased. As well, Klimesch et al., (1990) found that average alpha production decreased as normal subjects were given a long-term memory task (i.e. trying to remember some piece of information). Since active memorization requires a high degree of focused attention, it can be argued that the research of Klimesch et al. (1990) was indicative of alpha production during a high attention situation.

Based on the observed results and the confirming literature, it is the conclusion of this study that average alpha magnitude, in the occipital and parietal regions, is indeed indicative of the level of individual attention.

THETA

As with alpha, a great deal of research has focused on the significance of theta in the human EEG pattern. Se ral studies have reported that theta is linked to attention (e.g. Janzen & Fitzsimmons, 1995; Mann et al., 1992; Lubar et al. 1990; Holcomb et al., 1986; Satterfield & Schell, 1984; John, et al., 1983; and Fuller, 1977). Some clinicians (such as Lubar, 1991) even rely on average theta magnitude as one m of diagnosing attention deficit.

However, the results obtained in this thesis are not as conclusive as those reported in the above-mentioned studies. Average theta magnitude was not found to be significantly related to %EO (T.O.V.A.™ parameter for attention). Recall, that the correlations between alpha and %EO were no larger than –0.40. Although the direction (negative) of the theta vs. %EO correlation is consistent with the above-mentioned research, the magnitude is not statistically significant. A possible explanation for this is the fact that this study was limited in size and representativeness. Perhaps a larger, more representative study would have revealed more significant theta/%EO correlations.

The non-significant theta/%EO correlation is, however, consistent with the findings of researchers such as Nakashima & Sato (1992). They reported finding no significant relationship between the magnitude of theta and the level of concentration.

Large positive correlations were observed between average theta magnitude and %EC (T.O.V.A.™ parameter for impulsivity). Again, this result is not consistent with those reported in the literature. Matsuura et al. (1993) reported that ADHD (impulsive) children produced significantly greater average theta than normal controls. Again, the discrepancy between the results obtained in this study and those reported in the literature may likely be accounted for by the nature of the sample. However, this does not preclude the possibility that the result obtained in this thesis is the appropriate one. Further study is needed to test this hypothesis.

Another interesting finding pertaining to theta was that the T.O.V.A.™ parameters of %EO and %EC are highly correlated to each other (r = 0.88), but only %EC is significantly correlated to theta. This result helps to confirm the hypothesis that inattention and impulsivity are distinct traits.

DELTA

In chapter four it was discovered that a strong, negative relationship existed between average delta magnitude and the three T.O.V.A.™ parameters of %EO, %EC, and RTV. Although this relationship was found to be relatively strong in the central and midline regions, it was non-existent in the occipital and parietal regions. These findings are consistent with those of Matsuura et al. (1993), who reported that on-task delta was more prominent in normal controls than in the ADD or ADHD subjects.

<u>BETA</u>

One of the big surprises in this research thesis was the relative non-significance of beta as a correlate of attention. This is contrary to the findings of researchers such as Mann et al. (1992), and Lubar et al. (1990), who claim that the average magnitude of beta is one indicator an individual's level of attention. These researchers have claimed that beta is one of the bands which significantly differentiates between ADD/ADHD children and normal controls.

In this study, Beta1 and beta2 together were only found to correlate to reaction time. However, since reaction time cannot theoretically be considered an indicator of attention (an attentive person could have slow reflexes), this result was considered non-significant.

The findings of this thesis are consistent with those reported by Janzen et al. (1994). They found that average beta magnitude did not significantly differentiate between ADD children and normal controls.

<u>MULTIPLE REGRESSION</u>

The multiple regression analyses which were performed in chapter four established that there indeed exists a predictive relationship between EEG bands and T.O.V.A.™ parameters. These equations suggest that attention and impulsivity (at least with regard to a visual performance task) can be predicted using the average magnitudes of certain EEG bands (mainly alpha and delta) originating from certain cerebral locations (mainly occipital and parietal). As well, the equations suggest that both attention and impulsivity are controlled by the differential excitation and inhibition of certain EEG bands generated from specific cortical sites.

These findings are consistent with the work of Pfurtscheller (1992), who studied the affect of certain cognitive tasks on %ERD (decrease in average alpha production) and ERS (increase in average alpha production). Pfurtscheller (1992) discovered that during active cognition, certain areas of the brain exhibited %ERD, while others exhibited ERS. This finding led Pfurtscheller (1992) to conclude that during specific cognitive tasks, some areas of the brain were activated while others were inhibited. This is similar to the postulation put forth in this thesis, that attention and impulsivity are each a function of differential excitation and inhibition of specific waves, generated from specific cortical locations.

Another important note to mention was that two unique equations were found to exist: one for attention (%EO) and one for impulsivity (%EC). This provides further evidence to support the hypothesis that states that attention and impulsivity are two distinct constructs.

## Importance of Findings

The findings of this study, if substantiated, are of great consequence to medical professionals, psychologists, educators, and all those who conduct research on attention and impulsivity.

Although it had previously been known that certain EEG bands were related to attention and impulsivity, the correlational data from this study has helped to establish the cerebral locations where these relationships are strongest.

As well, the discovery of predictive relationships provides valuable insight into the natures of attention and impulsivity (in terms of EEG patterns). With further refinement, these predictive equations may be used to establish accurate diagnostic and training protocols. These protocols would be instrumental in the detection and remediation of attention deficit and impulsive individuals.

## Applicability of Findings

In recent years there has been a surge of interest in the area of EEG-neurofeedback training for individuals (especially children) with attention deficits. Those working in this area would greatly benefit from this research. The findings of this study indicate that an alpha/delta diagnostic and training paradigm should be used for the detection and training of those with attention deficits. For impulsivity, an alpha/beta2 paradigm would best serve the purpose (again, based on the results of this study).

Another applicable finding is the positioning of the electrodes in order to best measure the specific EEG bands which are related to attention and impulsivity. Based on the results of this study, the occipital (O1 and O2) and parietal (P3, P4, PZ) regions are of greatest consequence.

## SUGGESTIONS FOR FUTURE RESEARCH

Although this research has established that certain EEG bands are correlated to inattention and impulsivity, it was by no means a comprehensive treatise. Several related studies need to be conducted in order to confirm and generalize the findings of this thesis. First, a replication study is needed to establish the reliability of these findings. This completed, a larger study would then be required. This study would need to be more representative of the general population and include ADD and ADHD samples, as well. By using such a design, reliably generalizable equations could then be established.

Another interesting extension of this research would be to use the two predictive equations developed in this thesis to predict performance on the T.O.V.A.™ parameters of %EO and %EC. By statistically testing the accuracy of the predictions, the utility of the two equations could be ascertained.

## LIMITATIONS OF THE STUDY

As previously mentioned, the sample for this study was not representative of the general population. Therefore, any inferences based on this study cannot be generalized to all individuals. Also, the sample size of 16 was quite small, which further restricts the types of inferences which can be made.

The testing situation was another limitation of this study. The inclusion of pre- T.O.V.A.™ tasks led to a certain degree of boredom on the part of the subjects. By the time the T.O.V.A.™ task was begun, the subjects were quite bored and restless. Although, it may be argued that this added boredom may have helped polarize the sample (in terms of increasing the variance on the T.O.V.A.™).

Another complication, which resulted from the inclusion of the pre-T.O.V.A.™ tasks, was that EEG patterns were only recorded during the first half of the T.O.V.A.™. As mentioned in chapter three, the electrocap was removed early so as not to inconvenience the subjects, who had been wearing the electrocap for over one hour (the cap gets quite itchy). A future study would do well to preclude any prior tasks, and administer the full T.O.V.A.™ (while recording EEG data for the full 22 minutes).

## REFERENCES

Crosby, R.D., Corman, C.L., and Greenberg, L. (1993). The assessment of medication effects in attention deficit disorder using the Test of Variable of Attention (T.O.V.A.). Manuscript submitted for publication.

Dujardin, K., Derambure, P., Defebvre, L., Bouriez, J., Jacquesson, J., & Guieu, J. (1993). Evaluation of event-related desynchronization (ERD) during a recognition task: effect of attention. Electroencephalography and Clinical Neurophysiology, 86, 353-356.

Fein, G., Galin, D., Johnstone, J., Yingling, C., Marcus, M. & Kiersch (1983). EEG power spectra in normal and dyslexic children. 1. Reliability during passive conditions. Electroencephalography and Clinical Neurophysiology, 55, 399-405.

Fischbach, G. D. (1992). Mind and Brain. Scientific American, 266, 89-95.

Fischer-Williams, M. (1993). Brain tumors and other space occupying lesions (with a section on oncological CNS complications). In Ernest Niedermeyer and Fernando Lopes Da Silva (Eds.) Electroencephalography: Basic principles, clinical applications and related fields. Baltimore, MD: Williams & Wilkins, 263-289.

Fuller, P. (1977). Computer Estimated Alpha Attenuation During Problem Solving in Children With Learning Disabilities. Electroencephalography and Clinical Neurophysiology, 38, 149-156.

Graap, K. (1994). Test-retest reliability of EEG during baseline, reading, and drawing conditions in 10 to 12 year old boys. Unpublished Master's Thesis, University of Alberta.

Graap, K., Janzen, T., Norman, C., Fitzsimmons, G. (1994). One Week Test-Retest Reliability of EEG During Baseline and On-Task Conditions in 10 to 12 Year Old Boys. Manuscript submitted for publication.

Graap, K. (1994). Test-retest reliability of EEG during baseline, reading, and drawing conditions in 10 to 12 year old boys. Unpublished Master's Thesis, University of Alberta.

Greenberg, L., MD. (1987). An objective measure of methylphenidate response: Clinical use of the MCA. Psychopharmacology Bulletin, 23, 270-282.

Greenberg, L., MD. (1992). Treating Attention-Deficit Disorders in Children and Adults. The Psychiatric Times • Medicine & Behavior. 50, 18-19.

Greenberg, L., & Crosby, R.D. (1993). Specificity and Sensitivity of the Test of Variables of Attention (T.O.V.A.). Manuscript submitted for publication.

Grünewald-Zubergier, G. & Rasche, A. (1975). Hyperactive Behavior and EEG Arousal Reactions in Children. Electroencephalography and Clinical Neurophysiology, 38, 149-159.

Halperin, J., Wolf, L., Pascualvaca, D., Newcorn, J., Healey, J., O'Brian, J., Morganstein, A., & Young, G. (1988). Differential Assessment of Attention and Impulsivity in Children. Journal of The American Academy of Child and Adolescent Psychiatry, 27, 326-329.

Holcomb, P., Ackerman, P., & Dykman, R. (1986). Auditory Event-Related Potentials in Attention and Reading Disabled Boys. International Journal of Psychophysiology, 3, 263-273.

Janzen, T., Fitzsimmons, G. (1995). Theta: Towards and Electrophysiological marker of attention deficit disorder. Manuscript submitted for publication.

Janzen, T., Graap, K., Stephanson, S., Marshall, W., Fitzsimmons, G. (1994). Differences in Baseline EEG Measures for ADD and Normally Achieving Pre-adolescent Males. Manuscript submitted for publication.

Janzen, T. (1992). Comparing the dynamic EEG activity of successful and attention deficit disordered grade 5 and 6 boys. Unpublished Master's Thesis, University of Alberta.

John, E., Prichep, L., Ahn, H., Easton, P., Fridman, J., & Kaye, H. (1983). Neurometric Evaluation of Cognitive Dysfunction and Neurologic Disorders in Children. Progress in Neurobiology, 21, 239-290.

Kinsbourne, M. (1973). The control of Attention by Interaction Between the Cerebral Hemispheres. In S. Kornblum (Ed.), Attention and Performance IV. New York: Academic Press. Pp. 238-256.

Klimesch, W., Pfurtscheller, G., Mohl, W., and Schimke, H. (1990). Event-related desynchronization, ERD-mapping and hemispheric differences for words and numbers. International Journal of Psychophysiology, 8, 297-308.

Klorman, R., Salzman, L., Pass, H., Borgstedt, A., and Dainer, K. (1979). Effects of Methylphenidate on Hyperactive Children's Evoked Responses During Passive and Active Attention. Psychophysiology, 16, 23-29.

Lexicor Medical Technology (1990). Users Manual Neurosearch 24. Boulder, CO: Lexicor Medical Technology, Inc.

Lipold, O. (1973). The origin of the alpha rhythm. London: Churchill-Livingstone.

Lubar, J. L. (1985). EEG Biofeedback and Learning Disabilities. Theory Into Practice, 24, 106-111.

Lubar, J., Gross, D., Shively, M., & Mann, C. (1990). Differences Between Normal, Learning Disabled and Gifted Children Based Upon an Auditory Evoked Potential Task. International Journal of Psychophysiology, 4, 470-481.

Lubar, J. L. (1991). Discourse on the Development of EEG Diagnostics and Feedback for Attention-deficit/hyperactivity Disorders. Biofeedback and Self-Regulation, 16, 201-225.

Lubar, J., Bainchini, K., Calhoun, W., Lambert, E., Brody, Z., & Shabsin, H. (1985). Spectral Analysis of EEG Differences Between Children With and Without Learning Disabilities. Journal of Learning Disabilities, 18, 403-408.

Mann, C. A., Lubar, J.F., Zimmerman, A.W., Miller, C.A. & Muenchen, R.A. (1992). Quantitative analysis of EEG in boys with attention deficit disorder: Controlled study with clinical implications. Pediatric Neurology, 8, 30-36.

Matsuura, M., Okubo, Y., Toru, M., Kojima, T., He, Y., Hou, Y., Shen, Y., and Lee, C. (1993). A Cross-National EEG Study of Children with Emotional and Behavioral Problems: A WHO Collaborative Study in the Western Pacific Region. Biological Psychiatry, 34, 59-65.

Mulholland, T., & Evans, C. (1965). An unexpected artifact in the human electroencephalogram concerning the alpha rhythm and the orientation of the eyes. Nature, 207, 36-37.

Nakashima, K., & Sato, H. (1992). The effects of various mental tasks on appearance of frontal midline theta activity in EEG. Journal of Human Ergology, 21, 201-206.

Newbold, P. (1988). Statistics for business. Prentice Hall.

Niedermeyer, E. and Fernando Lopes Da Silva (Eds.) (1993). Electroencephalography: Basic Principles, Clinical Applications and Related Fields. Baltimore, MD: Williams & Wilkins.

Nuñez, P. (1981). Electric fields of the brain: the neurophysics of EEG. Oxford, England: Oxford University Press.

Pfurtscheller, G., and Berghold, A. (1989). Patterns of cortical activation during planning of voluntary movement. Electroencephalagraphy and Clinical Neurophysiology, 72, 250-258.

Raymond, N., Crosby, R., Corman, C., and Greenberg, L. (1993). Determinig Optimal Dose of Methylphenidate. Manuscript submitted for publication.

Satterfield, J., & Schell, A. (1984). Childhood Brain Function Differences in Delinquent and Non-delinquent Hyperactive Boys. Electroencephalography and Clinical Neurophysiology, 57, 199-207.

Sergeant, J., Geuze, R., and Van Winsum, W. (1987). Event-related desynchronization and P300. Psychophysiology, 24, 272-277.

Sykes, D., Douglas, V., Weiss, G., and Minde, K. (1971). Attention in Hyperactive Children and the Effect of Methylphenidate (Ritalin). Journal of child Psychology and Psychiatry, 12, 129-139.

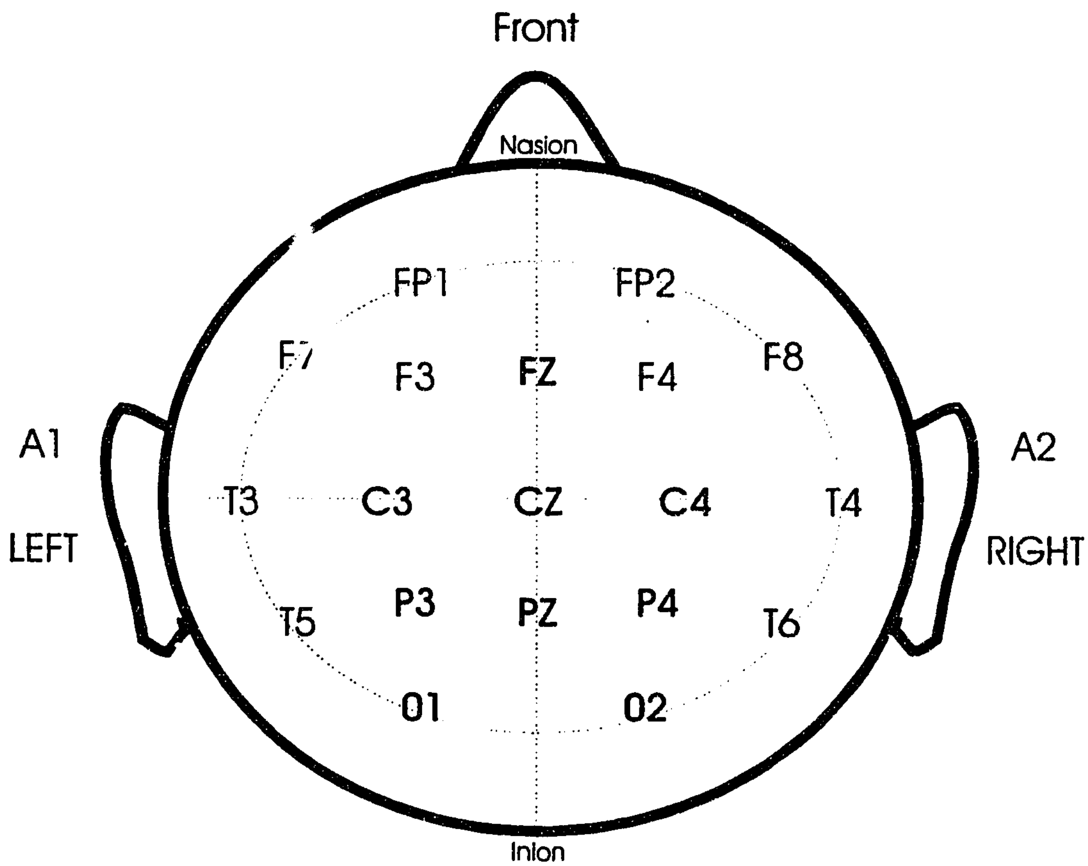
Sykes, D., Douglas, V., and Morgenstern, G. (1972). The effect of Methylphenidate (Ritalin) on Sustained Attention in Hyperactive Children. Psychopharmacologia, 25, 262-274.

Warren, L., & Haueter, E. (1981). Alpha asymmetry as a function of cognitive mode: the role of lateral eye movements. International Journal of Neuroscience, 13, 137-141.

Werry, J., and Aman, M. (1975). Methylphenidate and Haloperidol in Children. Archives of General Psychiatry, 32, 790-795.

# Appendix A

## The International 10/20 System of Electrode Placement




### Legend[1]

| | | | |
|---|---|---|---|
| F = Frontal | | Odd Numbers | = Left Hemisphere |
| C = Central | | Even Numbers | = Right Hemisphere |
| T = Temporal | | Z | = Midline |
| P = Parietal | | | |
| O = Occipital | | | |

[1] Adapted with permission from Janzen (1992)

# APPENDIX B

## TABLE B.1

## RAW DATA RESULTS FOR THE T.O.V.A.™ (11 MINUTES)

**TOVA Parameters Over the Entire 22 Minutes**

| ID# | o_11 | o_22 | %o_11 | %o_22 | c_11 | c_22 | %c_11 | %c_22 | rt_11 | rt_22 | var_11 | var_22 | %c.r. | %c.n.r. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 2 | 11 | 1 | 3 | 589 | 565 | 142 | 157 | 100 | 99 |
| 3 | 4 | 7 | 6 | 2 | 3 | 17 | 1 | 5 | 420 | 366 | 77 | 115 | 94 | 99 |
| 4 | 2 | 18 | 3 | 6 | 4 | 42 | 2 | 13 | 493 | 384 | 167 | 179 | 97 | 98 |
| 5 | 0 | 12 | 0 | 4 | 6 | 35 | 2 | 11 | 491 | 400 | 144 | 192 | 100 | 98 |
| 6 | 9 | 32 | 12 | 11 | 4 | 39 | 2 | 12 | 523 | 505 | 224 | 278 | 88 | 98 |
| 7 | 0 | 5 | 0 | 2 | 1 | 22 | 0 | 7 | 433 | 429 | 102 | 152 | 100 | 100 |
| 8 | 4 | 30 | 6 | 9 | 20 | 72 | 8 | 22 | 404 | 397 | 110 | 334 | 94 | 92 |
| 9 | 1 | 3 | 1 | 1 | 0 | 7 | 0 | 2 | 505 | 522 | 98 | 131 | 99 | 100 |
| 10 | 0 | 2 | 0 | 1 | 2 | 9 | 1 | 3 | 459 | 444 | 102 | 128 | 100 | 99 |
| 11 | 2 | 8 | 3 | 2 | 1 | 28 | 0 | 9 | 572 | 476 | 138 | 174 | 97 | 100 |
| 12 | 27 | 54 | 38 | 17 | 46 | 92 | 18 | 28 | 424 | 339 | 340 | 326 | 62 | 82 |
| 13 | 0 | 11 | 0 | 3 | 8 | 40 | 3 | 12 | 453 | 460 | 116 | 267 | 100 | 97 |
| 14 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 8 | 418 | 350 | 81 | 92 | 100 | 100 |
| 15 | 1 | 7 | 1 | 2 | 13 | 34 | 5 | 11 | 500 | 558 | 155 | 256 | 99 | 95 |
| 16 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 517 | 586 | 95 | 181 | 100 | 100 |
| 17 | 1 | 5 | 1 | 2 | 0 | 15 | 0 | 5 | 484 | 484 | 93 | 153 | 99 | 100 |

**Key to Symbols**

| Symbol | Description |
|---|---|
| o_11 | Omission errors after 11 minutes |
| o_22 | Omission errors after 22 minutes |
| %o_11 | Percent Omission errors after 11 minutes |
| %o_22 | Percent Omission errors after 22 minutes |
| c_11 | Commission errors after 11 minutes |
| c_22 | Commission errors after 22 minutes |
| %c_11 | Percent Commission errors after 11 minutes |
| %c_22 | Percent Commission errors after 22 minutes |
| rt_11 | Reaction time average over 11 minutes |
| rt_22 | Reaction time average over 22 minutes |
| var_11 | Variation of reaction time over 11 minutes |
| var_22 | Variation of reaction time over 22 minutes |
| %c.r. | Percent of correct responses made after 11 minutes |
| %c.n.r. | Percent of correct non-responses made after 11 minutes |

# APPENDIX B

TABLE B.2

RAW DATA RESULTS FOR THE T.O.V.A.™ (22 MINUTES)

**TOVA Parameters Recorded Over an Interval of 11 Minutes**

| ID# | o_11 | %o_11 | c_11 | %c_11 | rt_11 | var_11 |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 2 | 1 | 589 | 142 |
| 3 | 4 | 6 | 3 | 1 | 420 | 77 |
| 4 | 2 | 3 | 4 | 2 | 493 | 167 |
| 5 | 0 | 0 | 6 | 2 | 491 | 144 |
| 6 | 9 | 12 | 4 | 2 | 523 | 224 |
| 7 | 0 | 0 | 1 | 0 | 433 | 102 |
| 8 | 4 | 6 | 20 | 8 | 404 | 110 |
| 9 | 1 | 1 | 0 | 0 | 505 | 98 |
| 10 | 0 | 0 | 2 | 1 | 459 | 102 |
| 11 | 2 | 3 | 1 | 0 | 572 | 138 |
| 12 | 27 | 38 | 46 | 18 | 424 | 340 |
| 13 | 0 | 0 | 8 | 3 | 453 | 116 |
| 14 | 0 | 0 | [illegible] | [illegible] | 418 | 81 |
| 15 | 1 | 1 | 13 | [illegible] | 500 | 155 |
| 16 | 0 | 0 | [illegible] | [illegible] | 517 | 95 |
| 17 | 1 | 1 | [illegible] | 0 | 484 | 93 |

**Key to Symbols**

| Symbol | **Description** |
|---|---|
| **o_11** | Omission errors after 11 minutes |
| **%o_11** | Percent Omission errors after 11 minutes |
| **c_11** | Commission errors after 11 minutes |
| **%c_11** | Percent Commission errors after 11 minutes |
| **rt_11** | Reaction time average over 11 minutes |
| **var_11** | Variation of reaction time over 11 minutes |

# APPENDIX C

## TABLE C.1

## RAW DATA RESULTS OF EEG RECORDINGS (DELTA)

**Average Magnitudes of Delta Per Site**

| ID# | d_c3 | d_c4 | d_cz | d_fz | d_o1 | d_o2 | d_p3 | d_p4 | d_pz | Delta_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 26.10 | 24.60 | 27.90 | 24.90 | 25.70 | 24.20 | 25.50 | 25.10 | 26.00 | 25.56 |
| 3 | 28.50 | 29.90 | 30.40 | 27.00 | 40.50 | 35.70 | 33.50 | 35.20 | 31.40 | 32.46 |
| 4 | 24.10 | 24.30 | 28.40 | 25.60 | 25.60 | 24.00 | 26.40 | 24.30 | 28.00 | 25.63 |
| 5 | 25.40 | 26.20 | 32.00 | 26.20 | 25.80 | 24.60 | 24.50 | 26.10 | 27.80 | 26.51 |
| 6 | 25.10 | 25.90 | 28.00 | 22.00 | 26.80 | 27.50 | 27.40 | 27.10 | 28.40 | 26.47 |
| 7 | 26.10 | 28.30 | 31.30 | 28.70 | 27.00 | 23.30 | 26.30 | 27.20 | 29.50 | 27.52 |
| 8 | 21.90 | 23.00 | 26.40 | 23.30 | 21.50 | 20.50 | 25.30 | 23.90 | 27.00 | 23.64 |
| 9 | 22.50 | 23.30 | 26.30 | 23.60 | 24.20 | 25.10 | 21.40 | 19.70 | 22.00 | 23.12 |
| 10 | 21.60 | 22.40 | 24.10 | 21.70 | 25.70 | 27.60 | 25.10 | 27.00 | 27.30 | 24.72 |
| 11 | 24.20 | [illegible] | 26.20 | 24.40 | 25.40 | 23.90 | 28.00 | 27.70 | 30.00 | 25.91 |
| 12 | 18.70 | 20.20 | 21.60 | 19.70 | 30.10 | 26.00 | 24.40 | 24.80 | 24.30 | 23.31 |
| 13 | 23.10 | 22.90 | 25.50 | 25.70 | 19.10 | 18.80 | 23.90 | 22.50 | 23.00 | 22.72 |
| 14 | 24.20 | 22.80 | 26.70 | 23.10 | 26.60 | 24.80 | 24.00 | 21.90 | 23.20 | 24.14 |
| 15 | 24.50 | 27.60 | 28.20 | 26.50 | 26.00 | 29.30 | 26.20 | 28.90 | 28.80 | 27.33 |
| 16 | 30.50 | 30.20 | 28.30 | 27.80 | 27.80 | 29.80 | 32.50 | 32.20 | 31.50 | 30.12 |
| 17 | 25.50 | 25.00 | 27.20 | 24.80 | 26.40 | 26.80 | 26.70 | 26.60 | 29.10 | 26.46 |

**Standard Deviations of Delta Per Site**

| ID# | d.sd_c3 | d.sd_c4 | d.sd_cz | d.sd_fz | d.sd_o1 | d.sd_o2 | d.sd_p3 | d.sd_p4 | d.sd_pz | d.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.90 | 8.20 | 8.60 | 8.80 | 8.50 | 7.80 | 9.10 | 8.80 | 8.60 | 8.59 |
| 3 | 10.00 | 10.50 | 10.70 | 8.80 | 16.50 | 14.70 | 11.70 | 13.20 | 11.10 | 11.91 |
| 4 | 8.20 | 9.50 | 9.80 | 9.10 | 9.00 | 8.50 | 8.80 | 8.40 | 9.40 | 8.97 |
| 5 | 9.90 | 9.60 | 11.60 | 9.00 | 9.60 | 7.90 | 9.70 | 10.30 | 11.50 | 9.90 |
| 6 | 8.80 | 9.20 | 10.10 | 6.60 | 11.10 | 12.30 | 11.30 | 11.20 | 11.40 | 10.22 |
| 7 | 10.10 | 11.70 | 12.80 | 10.90 | 10.80 | 10.40 | 10.20 | 11.40 | 11.90 | 11.13 |
| 8 | 6.80 | 7.30 | 9.20 | 7.70 | 7.30 | 7.20 | 8.50 | 7.80 | 9.10 | 7.88 |
| 9 | 8.40 | 8.80 | 9.30 | 8.60 | 8.60 | 9.30 | 6.90 | 6.70 | 7.10 | 8.19 |
| 10 | 6.50 | 8.70 | 8.20 | 6.80 | 8.00 | 8.70 | 8.10 | 9.00 | 8.90 | 8.10 |
| [illegible] | 9.20 | 9.40 | 9.90 | 7.90 | 9.40 | 8.60 | 12.70 | 11.90 | 13.00 | 10.22 |
| 12 | 6.60 | 6.60 | 7.50 | 7.20 | 14.90 | 10.40 | 10.50 | 8.90 | 8.60 | 9.02 |
| 13 | 8.50 | 7.20 | 9.20 | 9.40 | 5.60 | 5.30 | 8.80 | 6.90 | 7.70 | 7.62 |
| 14 | 9.20 | 7.80 | 10.40 | 7.70 | 9.70 | 8.70 | 8.40 | 7.30 | 7.70 | 8.54 |
| 15 | 8.40 | 9.80 | 9.40 | 8.50 | 11.70 | 11.30 | 10.70 | 10.90 | 10.70 | 10.16 |
| 16 | 11.30 | 11.60 | 10.10 | 9.00 | 9.40 | 10.30 | 11.90 | 11.70 | 11.90 | 10.80 |
| 17 | 7.30 | 7.50 | 8.70 | 7.20 | 8.40 | 8.50 | 9.20 | 8.00 | 9.60 | 8.27 |

# APPENDIX C

## TABLE C.2

## RAW DATA RESULTS OF EEG RECORDINGS (THETA)

**Average Magnitudes of Theta per Site**

| ID# | th_c3 | th_c4 | th_cz | th_fz | th_o1 | th_o2 | th_p3 | th_p4 | th_pz | Theta_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16.60 | 17.60 | 20.10 | 16.10 | 18.50 | 15.60 | 17.00 | 17.80 | 18.80 | 17.57 |
| 3 | 20.70 | 20.80 | 22.40 | 21.20 | 22.50 | 20.50 | 20.30 | 22.10 | 21.00 | 21.28 |
| 4 | 20.50 | 20.50 | 24.40 | 21.40 | 19.40 | 20.10 | 20.10 | 20.70 | 21.80 | 20.99 |
| 5 | 20.70 | 21.60 | 26.40 | 23.00 | 23.80 | 24.80 | 22.20 | 25.30 | 26.10 | 23.77 |
| 6 | 20.40 | 20.40 | 22.80 | 19.00 | 17.60 | 19.00 | 19.90 | 20.50 | 20.70 | 20.03 |
| 7 | 24.70 | 23.60 | 30.10 | 26.90 | 21.20 | 18.90 | 24.60 | 24.60 | 27.80 | 24.71 |
| 8 | 17.50 | 17.40 | 21.00 | 19.50 | 15.30 | 14.60 | 17.10 | 16.00 | 18.60 | 17.44 |
| 9 | 18.30 | 18.40 | 24.60 | 19.00 | 12.90 | 13.10 | 15.50 | 15.00 | 16.80 | 17.07 |
| 10 | 16.90 | 17.30 | 21.20 | 18.70 | 13.60 | 15.70 | 16.30 | 16.90 | 17.60 | 17.13 |
| 11 | 23.20 | 24.40 | 25.10 | 24.00 | 23.30 | 24.30 | 28.10 | 32.00 | 31.00 | 26.16 |
| 12 | 15.20 | 16.90 | 18.60 | 17.40 | 21.00 | 18.10 | 18.30 | 16.90 | 17.70 | 17.79 |
| 13 | 17.80 | 16.80 | 19.70 | 20.40 | 15.50 | 15.20 | 17.40 | 16.80 | 16.20 | 17.31 |
| 14 | 19.80 | 19.30 | 23.70 | 18.50 | 18.70 | 16.50 | 20.40 | 18.60 | 19.80 | 19.48 |
| 15 | 16.00 | 17.30 | 19.10 | 17.00 | 20.00 | 19.10 | 18.00 | 19.40 | 19.70 | 18.40 |
| 16 | 25.10 | 24.40 | 26.50 | 24.00 | 20.50 | 20.90 | 25.00 | 24.30 | 25.30 | 24.00 |
| 17 | 19.40 | 20.00 | 22.30 | 21.00 | 18.80 | 18.60 | 18.70 | 18.30 | 19.50 | 19.62 |

**Standard Deviations of Theta per Site**

| ID# | th.sd_c3 | th.sd_c4 | th.sd_cz | th.sd_fz | th.sd_o1 | th.sd_o2 | th.sd_p3 | th.sd_p4 | th.sd_pz | th_sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.80 | 5.60 | 7.30 | 5.50 | 6.60 | 5.10 | 5.30 | 5.40 | 6.10 | 5.86 |
| 3 | 6.70 | 8.00 | 7.80 | 7.40 | 8.30 | 6.80 | 6.60 | 6.80 | 6.60 | 7.22 |
| 4 | 6.60 | 6.80 | 8.00 | 6.50 | 6.70 | 6.90 | 6.70 | 7.00 | 7.50 | 6.97 |
| 5 | 7.80 | 7.40 | 9.00 | 7.20 | 7.70 | 7.20 | 6.20 | 7.40 | 7.50 | 7.49 |
| 6 | 7.20 | 6.40 | 7.70 | 5.70 | 6.60 | 6.80 | 9.10 | 8.80 | 6.60 | 7.43 |
| 7 | 8.30 | 8.20 | 11.30 | 10.40 | 7.30 | 6.30 | 8.80 | 9.10 | 10.90 | 8.96 |
| 8 | 6.50 | 5.60 | 7.30 | 6.60 | 4.90 | 4.80 | 5.70 | 4.90 | 6.10 | 5.82 |
| 9 | 5.70 | 6.30 | 8.40 | 6.00 | 3.90 | 4.30 | 5.10 | 5.40 | 5.80 | 5.66 |
| 10 | 4.70 | 4.80 | 5.80 | 5.40 | 4.20 | 5.20 | 4.40 | 5.10 | 5.80 | 5.04 |
| 11 | 7.40 | 7.00 | 7.20 | 8.50 | 8.20 | 9.60 | 9.60 | 10.20 | 10.40 | 8.68 |
| 12 | 4.70 | 6.00 | 6.80 | 6.40 | 9.50 | 6.80 | 6.80 | 5.70 | 6.20 | 6.54 |
| 13 | 5.10 | 5.40 | 6.10 | 5.80 | 5.00 | 4.80 | 5.20 | 5.30 | 5.10 | 5.31 |
| 14 | 5.50 | 5.60 | 6.80 | 5.70 | 6.40 | 4.90 | 5.90 | 5.50 | 5.60 | 5.77 |
| 15 | 4.50 | 5.50 | 5.70 | 4.90 | 10.10 | 7.50 | 5.40 | 6.40 | 5.90 | 6.21 |
| 16 | 10.90 | 8.60 | 11.70 | 9.60 | 8.60 | 8.10 | 11.30 | 9.40 | 10.40 | 9.84 |
| 17 | 6.60 | 6.60 | 8.20 | 6.80 | 6.60 | 6.50 | 6.00 | 5.90 | 6.20 | 6.60 |

# APPENDIX C

## TABLE C.3

## RAW DATA RESULTS OF EEG RECORDINGS (ALPHA)

### Average Magnitudes of Alpha per Site

| ID# | a_c3 | a_c4 | a_cz | a_fz | a_o1 | a_o2 | a_p3 | a_p4 | a_pz | Alpha_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.30 | 14.30 | 14.00 | 11.10 | 17.80 | 15.50 | 15.50 | 16.80 | 16.60 | 14.99 |
| 3 | 11.50 | 13.10 | 12.40 | 10.70 | 20.60 | 16.30 | 15.10 | 17.70 | 16.20 | 14.84 |
| 4 | 16.10 | 17.80 | 17.80 | 14.20 | 21.50 | 21.10 | 19.60 | 18.20 | 21.70 | 18.67 |
| 5 | 12.00 | 11.50 | 13.90 | 13.30 | 19.90 | 20.20 | 13.10 | 15.30 | 15.20 | 14.93 |
| 6 | 16.30 | 27.00 | 20.20 | 12.60 | 24.60 | 28.40 | 24.40 | 30.90 | 28.90 | 23.70 |
| 7 | 19.20 | 24.50 | 24.70 | 17.40 | 29.70 | 24.60 | 23.60 | 29.10 | 29.00 | 24.64 |
| 8 | 14.00 | 17.40 | 23.00 | 12.50 | 14.20 | 14.20 | 16.90 | 16.50 | 19.10 | 16.42 |
| 9 | 10.70 | 11.00 | 11.70 | 10.10 | 14.80 | 14.40 | 10.80 | 10.80 | 10.40 | 11.63 |
| 10 | 13.40 | 13.60 | 16.10 | 12.60 | 19.90 | 27.30 | 15.70 | 21.00 | 21.20 | 17.87 |
| 11 | 14.80 | 17.30 | 15.40 | 13.20 | 24.60 | 29.00 | 18.30 | 24.00 | 21.20 | 19.76 |
| 12 | 20.90 | 24.10 | 22.90 | 20.40 | 56.50 | 48.00 | 39.10 | 32.60 | 33.20 | 33.08 |
| 13 | 22.70 | 24.60 | 28.00 | 18.30 | 19.20 | 18.50 | 26.80 | 27.20 | 26.60 | 23.54 |
| 14 | 14.20 | 14.80 | 15.80 | 13.00 | 33.10 | 33.90 | 15.50 | 17.20 | 15.70 | 19.24 |
| 15 | 17.30 | 17.50 | 18.30 | 13.70 | 31.70 | 36.50 | 22.90 | 24.40 | 25.70 | 23.11 |
| 16 | 20.40 | 27.70 | 19.40 | 18.20 | 20.30 | 21.00 | 22.30 | 22.80 | 23.10 | 21.69 |
| 17 | 19.60 | 20.30 | 25.00 | 15.40 | 23.20 | 23.70 | 22.10 | 20.30 | 24.50 | 21.57 |

### Standard Deviations of Alpha per Site

| ID# | a.sd_c3 | a.sd_c4 | a.sd_cz | a.sd_fz | a.sd_o1 | a.sd_o2 | a.sd_p3 | a.sd_p4 | a.sd_pz | a.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.40 | 5.20 | 4.70 | 3.60 | 6.30 | 6.20 | 5.40 | 6.70 | 6.90 | 5.49 |
| 3 | 3.50 | 5.20 | 4.30 | 3.50 | 9.60 | 7.00 | 6.00 | 9.50 | 8.30 | 6.32 |
| 4 | 6.40 | 6.30 | 6.20 | 5.10 | 11.40 | 10.60 | 10.30 | 8.50 | 11.40 | 8.47 |
| 5 | 3.10 | 3.50 | 4.70 | 3.90 | 5.80 | 7.30 | 3.40 | 5.10 | 4.40 | 4.58 |
| 6 | 8.50 | 13.20 | 9.80 | 6.10 | 12.10 | 14.10 | 14.40 | 15.90 | 17.70 | 12.42 |
| 7 | 7.50 | 9.20 | 9.40 | 5.90 | 15.00 | 12.40 | 10.20 | 15.30 | 13.90 | 10.98 |
| 8 | 5.10 | 7.30 | 8.80 | 4.20 | 4.90 | 5.30 | 6.90 | 6.50 | 7.30 | 6.26 |
| 9 | 4.00 | 4.00 | 3.80 | 3.40 | 6.60 | 5.60 | 4.10 | 3.20 | 3.40 | 4.23 |
| 10 | 5.70 | 4.80 | 6.00 | 4.70 | 8.70 | 13.50 | 6.80 | 9.20 | 9.90 | 7.70 |
| 11 | 4.60 | 6.20 | 5.30 | 4.10 | 11.60 | 12.00 | 7.80 | 10.40 | 8.90 | 7.88 |
| 12 | 9.40 | 10.60 | 9.70 | 7.40 | 22.80 | 19.40 | 18.00 | 16.80 | 16.40 | 14.50 |
| 13 | 11.50 | 10.30 | 11.60 | 8.30 | 7.30 | 6.90 | 10.70 | 11.50 | 9.80 | 9.74 |
| 14 | 4.80 | 6.20 | 5.90 | 4.60 | 15.90 | 16.70 | 5.90 | 7.20 | 6.10 | 8.14 |
| 15 | 8.10 | 7.40 | 8.00 | 5.60 | 18.80 | 21.10 | 12.30 | 13.10 | 13.70 | 12.01 |
| 16 | 10.40 | 12.00 | 8.50 | 6.30 | 11.70 | 13.10 | 11.50 | 11.50 | 12.20 | 10.80 |
| 17 | 7.80 | 8.50 | 11.20 | 5.20 | 9.10 | 9.90 | 8.90 | 6.90 | 9.40 | 8.54 |

# APPENDIX C

TABLE C.4

RAW DATA RESULTS OF EEG RECORDINGS (SMR)

**Average Magnitudes of Beta1 per Site**

| ID# | b1_c3 | b1_c4 | b1_cz | b1_fz | b1_o1 | b1_o2 | b1_p3 | b1_p4 | b1_pz | Beta1_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.20 | 5.60 | 5.60 | 5.20 | 5.10 | 4.50 | 5.10 | 5.20 | 5.00 | 5.17 |
| 3 | 7.70 | 7.60 | 7.40 | 7.00 | 8.00 | 7.30 | 7.50 | 7.50 | 7.00 | 7.44 |
| 4 | 5.30 | 5.30 | 5.60 | 6.30 | 5.60 | 6.00 | 5.30 | 5.40 | 5.10 | 5.54 |
| 5 | 5.10 | 5.50 | 6.50 | 6.70 | 7.80 | 6.40 | 5.80 | 5.60 | 5.70 | 6.12 |
| 6 | 6.80 | 7.90 | 7.10 | 6.20 | 7.00 | 7.40 | 7.40 | 7.70 | 7.20 | 7.19 |
| 7 | 8.30 | 9.20 | 9.30 | 8.20 | 9.70 | 9.30 | 9.40 | 10.30 | 11.00 | 9.41 |
| 8 | 6.50 | 6.70 | 7.00 | 6.70 | 6.40 | 7.50 | 6.70 | 6.50 | 7.00 | 6.78 |
| 9 | 5.50 | 5.50 | 5.90 | 5.30 | 6.80 | 6.50 | 5.80 | 5.30 | 5.30 | 5.77 |
| 10 | 6.80 | 6.90 | 7.00 | 6.80 | 7.30 | 7.40 | 8.00 | 7.40 | 7.60 | 7.24 |
| 11 | 6.20 | 6.40 | 6.10 | 6.10 | 7.00 | 8.00 | 6.30 | 6.70 | 6.50 | 6.59 |
| 12 | 6.30 | 7.00 | 6.60 | 6.10 | 11.90 | 10.20 | 9.00 | 8.10 | 8.40 | 8.18 |
| 13 | 9.50 | 9.50 | 10.00 | 9.40 | 10.00 | 10.00 | 10.00 | 9.40 | 8.70 | 9.61 |
| 14 | 6.50 | 6.30 | 6.70 | 7.10 | 6.90 | 6.60 | 6.90 | 6.80 | 6.20 | 6.67 |
| 15 | 7.20 | 8.30 | 8.10 | 8.80 | 8.10 | 9.60 | 7.50 | 8.80 | 8.60 | 8.33 |
| 16 | 12.80 | 14.50 | 11.10 | 11.10 | 9.60 | 10.10 | 13.50 | 12.50 | 11.90 | 11.90 |
| 17 | 7.40 | 7.90 | 8.00 | 8.60 | 9.50 | 8.80 | 7.50 | 7.40 | 7.70 | 8.09 |

**Standard Deviations of Beta1 per Site**

| ID# | b1.sd_c3 | b1.sd_c4 | b1.sd_cz | b1.sd_fz | b1.sd_o1 | b1.sd_o2 | b1.sd_p3 | b1.sd_p4 | b1.sd_pz | b1.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.70 | 1.70 | 1.60 | 1.70 | 1.60 | 1.30 | 1.50 | 1.50 | 1.50 | 1.57 |
| 3 | 2.60 | 2.80 | 2.30 | 2.20 | 2.80 | 2.30 | 2.60 | 2.40 | 2.30 | 2.48 |
| 4 | 1.40 | 1.40 | 1.40 | 1.90 | 1.80 | 1.90 | 1.50 | 1.50 | 1.60 | 1.60 |
| 5 | 1.40 | 1.60 | 1.90 | 1.70 | 3.10 | 2.20 | 1.60 | 1.70 | 1.70 | 1.91 |
| 6 | 2.10 | 3.40 | 2.30 | 1.90 | 2.40 | 2.60 | 3.00 | 3.20 | 3.20 | 2.68 |
| 7 | 3.00 | 3.70 | 3.90 | 2.70 | 4.20 | 3.70 | 4.40 | 5.00 | 5.90 | 4.06 |
| 8 | 2.10 | 2.00 | 2.20 | 2.10 | 2.00 | 2.00 | 2.00 | 1.90 | 2.10 | 2.04 |
| 9 | 2.00 | 1.60 | 1.70 | 1.40 | 2.10 | 2.10 | 1.90 | 1.70 | 1.60 | 1.79 |
| 10 | 2.10 | 2.70 | 2.40 | 2.00 | 2.90 | 3.10 | 2.80 | 3.10 | 2.90 | 2.67 |
| 11 | 1.70 | 1.90 | 1.50 | 1.60 | 2.00 | 2.40 | 1.80 | 2.10 | 2.10 | 1.90 |
| 12 | 2.30 | 2.20 | 2.30 | 1.80 | 4.60 | 3.90 | 3.70 | 3.10 | 3.30 | 3.02 |
| 13 | 3.30 | 3.60 | 3.90 | 3.40 | 4.00 | 2.50 | 3.30 | 2.40 | 3.20 | 3.29 |
| 14 | 1.90 | 2.00 | 2.00 | 2.10 | 2.20 | 2.20 | 2.00 | 2.00 | 1.70 | 2.01 |
| 15 | 2.50 | 2.60 | 2.80 | 2.90 | 3.00 | 3.90 | 2.50 | 3.10 | 3.00 | 2.92 |
| 16 | 4.70 | 5.80 | 4.30 | 4.10 | 3.00 | 2.90 | 4.50 | 4.10 | 4.10 | 4.17 |
| 17 | 2.00 | 2.50 | 2.30 | 2.60 | 3.10 | 2.90 | 2.40 | 2.20 | 2.50 | 2.50 |

# Appendix C

## Table C.5

## Raw Data Results of EEG Recordings (Beta1)

**Average Magnitudes of Beta2 Per Site**

| ID# | b2_c3 | b2_c4 | b2_cz | b2_fz | b2_o1 | b2_o2 | b2_p3 | b2_p4 | b2_pz | Beta2_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.00 | 4.10 | 4.00 | 3.90 | 3.80 | 3.50 | 3.60 | 3.60 | 3.40 | 3.77 |
| 3 | 5.20 | 4.80 | 5.00 | 4.70 | 5.20 | 5.50 | 4.70 | 4.40 | 4.20 | 4.86 |
| 4 | 4.80 | 5.00 | 4.90 | 5.80 | 4.80 | 5.70 | 4.50 | 4.40 | 4.30 | 4.91 |
| 5 | 4.70 | 4.70 | 5.20 | 6.40 | 7.20 | 5.30 | 5.00 | 4.40 | 4.50 | 5.27 |
| 6 | 5.60 | 6.30 | 5.60 | 5.10 | 5.30 | 5.40 | 5.40 | 5.50 | 5.00 | 5.47 |
| 7 | 6.40 | 6.40 | 6.90 | 6.50 | 6.70 | 7.10 | 6.30 | 6.50 | 6.80 | 6.62 |
| 8 | 5.00 | 5.30 | 5.40 | 5.80 | 5.20 | 7.60 | 4.80 | 5.00 | 4.60 | 5.41 |
| 9 | 4.50 | 4.50 | 4.70 | 4.40 | 4.90 | 4.50 | 4.30 | 4.40 | 4.20 | 4.49 |
| 10 | 4.80 | 4.40 | 4.90 | 5.20 | 5.20 | 5.10 | 4.70 | 4.50 | 4.60 | 4.82 |
| 11 | 4.60 | 5.00 | 4.60 | 4.50 | 5.80 | 6.80 | 4.70 | 4.80 | 4.50 | 5.03 |
| 12 | 4.70 | 5.10 | 4.90 | 5.00 | 8.00 | 6.90 | 5.60 | 5.30 | 5.00 | 5.61 |
| 13 | 7.10 | 7.20 | 6.80 | 7.40 | 9.10 | 9.30 | 6.70 | 6.90 | 5.70 | 7.36 |
| 14 | 4.70 | 4.60 | 4.80 | 4.70 | 5.80 | 5.80 | 5.10 | 5.10 | 4.70 | 5.03 |
| 15 | 6.90 | 7.70 | 7.70 | 9.90 | 5.80 | 6.10 | 5.50 | 5.60 | 5.60 | 6.76 |
| 16 | 7.70 | 9.60 | 6.80 | 6.90 | 5.50 | 5.60 | 6.90 | 6.40 | 5.90 | 6.81 |
| 17 | 6.60 | 6.70 | 6.80 | 7.80 | 7.10 | 6.40 | 6.80 | 5.80 | 6.20 | 6.69 |

Standard Deviations of Beta2 Per Site

| ID# | b2.sd_c3 | b2.sd_c4 | b2.sd_cz | b2.sd_fz | b2.sd_o1 | b2.sd_o2 | b2.sd_p3 | b2.sd_p4 | b2.sd_pz | b2.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.20 | 1.40 | 1.20 | 1.20 | 1.10 | 1.10 | 1 | 1 | 0.90 | 1.12 |
| 3 | 1.70 | 1.40 | 1.50 | 1.60 | 1.60 | 1.50 | 1.5 | 1.3 | 1.30 | 1.49 |
| 4 | 1.40 | 1.60 | 1.30 | 2.00 | 1.70 | 1.70 | 1.4 | 1.1 | 1.20 | 1.49 |
| 5 | 1.50 | 1.20 | 1.40 | 1.80 | 3.50 | 2.30 | 1.4 | 1.3 | 1.40 | 1.76 |
| 6 | 2.00 | 1.70 | 1.80 | 1.40 | 1.70 | 1.50 | 1.9 | 1.9 | 1.60 | 1.72 |
| 7 | 2.30 | 2.40 | 2.30 | 1.90 | 2.10 | 2.00 | 2.4 | 2.7 | 2.80 | 2.32 |
| 8 | 1.50 | 1.50 | 1.60 | 1.70 | 1.60 | 2.30 | 1.2 | 1.5 | 1.40 | 1.59 |
| 9 | 1.60 | 1.40 | 1.60 | 1.30 | 1.50 | 1.30 | 1.2 | 1.2 | 1.20 | 1.37 |
| 10 | 1.80 | 1.40 | 1.50 | 1.70 | 2.00 | 1.90 | 1.6 | 1.4 | 1.30 | 1.62 |
| 11 | 1.50 | 1.60 | 1.30 | 1.40 | 1.70 | 1.90 | 1.3 | 1.5 | 1.50 | 1.52 |
| 12 | 1.40 | 1.80 | 1.40 | 1.40 | 2.80 | 2.40 | 1.9 | 1.8 | 1.70 | 1.84 |
| 13 | 1.70 | 2.20 | 1.90 | 2.30 | 3.90 | 2.90 | 1.9 | 2.1 | 1.60 | 2.28 |
| 14 | 1.40 | 1.40 | 1.60 | 1.50 | 2.30 | 2.50 | 1.6 | 1.6 | 1.50 | 1.71 |
| 15 | 3.00 | 3.00 | 3.50 | 4.40 | 1.90 | 1.80 | 1.8 | 1.5 | 1.60 | 2.50 |
| 16 | 3.00 | 4.60 | 2.50 | 2.60 | 1.70 | 1.60 | 2.3 | 2.1 | 2.00 | 2.49 |
| 17 | 2.00 | 2.00 | 2.10 | 2.20 | 2.40 | 2.20 | 2.4 | 1.9 | 2.00 | 2.13 |

# APPENDIX C

## TABLE C.6

## RAW DATA RESULTS OF EEG RECORDINGS (BETA2)

**Average Magnitudes of Beta All per Site**

| ID# | bt_c3 | bt_c4 | bt_cz | bt_fz | bt_o1 | bt_o2 | b2_p3 | b2_p4 | bt_pz | BetaT_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.80 | 5.60 | 5.80 | 5.60 | 5.60 | 5.30 | 3.60 | 3.60 | 5.20 | 5.12 |
| 3 | 6.50 | 6.80 | 6.60 | 6.20 | 7.60 | 9.60 | 4.70 | 4.40 | 6.40 | 6.53 |
| 4 | 6.80 | 6.50 | 6.90 | 6.80 | 7.00 | 9.40 | 4.50 | 4.40 | 6.60 | 6.54 |
| 5 | 8.80 | 8.10 | 8.60 | 12.50 | 14.40 | 10.70 | 5.00 | 4.40 | 8.20 | 8.97 |
| 6 | 7.30 | 7.80 | 8.00 | 7.10 | 7.40 | 7.90 | 5.40 | 5.50 | 7.20 | 7.07 |
| 7 | 7.30 | 7.40 | 7.40 | 8.00 | 10.60 | 13.40 | 6.30 | 6.50 | 7.50 | 8.27 |
| 8 | [illegible] | 7.20 | 6.70 | 6.90 | 9.20 | 13.70 | 4.80 | 5.00 | 6.20 | 7.32 |
| 9 | [illegible] | [illegible] | 6.10 | 6.20 | 7.20 | 6.60 | 4.30 | 4.40 | 5.80 | 5.88 |
| 10 | [illegible] | [illegible] | 7.10 | 7.70 | 8.50 | 9.20 | 4.70 | 4.50 | 7.90 | 7.19 |
| 11 | [illegible] | [illegible] | 7.80 | 8.20 | 10.00 | 12.00 | 4.70 | 4.80 | 7.10 | 7.91 |
| 12 | 6.50 | 6.30 | 6.40 | 6.00 | 11.50 | 10.10 | 5.60 | 5.30 | 7.40 | 7.23 |
| 13 | 9.60 | 10.10 | 8.50 | 10.70 | 17.30 | 21.50 | 6.70 | 6.90 | 7.60 | 10.99 |
| 14 | 6.60 | 6.40 | 6.60 | 6.40 | 7.60 | 7.80 | 5.10 | 5.10 | 6.40 | 6.44 |
| 15 | 7.90 | 7.90 | 7.80 | 8.20 | 8.50 | 8.80 | 5.50 | [illegible] | 7.10 | 7.48 |
| 16 | 8.40 | 9.70 | 7.90 | 7.60 | 7.50 | 8.40 | 6.90 | [illegible] | 7.30 | 7.79 |
| 17 | 9.00 | 9.00 | 8.10 | 8.90 | 11.80 | 9.90 | 6.80 | [illegible] | 8.10 | 8.60 |

**Standard Deviations of Beta All per Site**

| ID# | bt.sd_c3 | bt.sd_c4 | bt.sd_cz | bt.sd_fz | bt.sd_o1 | bt.sd_o2 | b2.sd_p3 | b2.sd_p4 | bt.sd_pz | bt.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.90 | 2.70 | 2.60 | 2.60 | 3.10 | 2.50 | 1.00 | 1.00 | 2.70 | 2.34 |
| 3 | 5.30 | 5.20 | 4.70 | 4.90 | 6.80 | 5.30 | 1.50 | 1.30 | 5.20 | 4.47 |
| 4 | 3.60 | 3.30 | 3.10 | 3.50 | 4.60 | 4.10 | 1.40 | 1.10 | 3.70 | 3.16 |
| 5 | 2.20 | 2.50 | 3.00 | 3.10 | 6.60 | 4.20 | 1.40 | 1.30 | 3.40 | 3.08 |
| 6 | 4.20 | 4.60 | 4.00 | 3.00 | 3.40 | 3.30 | 1.90 | 1.90 | 5.20 | 3.50 |
| 7 | 4.70 | 5.10 | 5.70 | 4.50 | 6.30 | 5.10 | 2.40 | 2.70 | 8.30 | 4.98 |
| 8 | 4.00 | 3.60 | 3.70 | 3.50 | 4.30 | 5.00 | 1.20 | 1.50 | 4.10 | 3.43 |
| 9 | 3.20 | 3.00 | 3.10 | 2.80 | 4.70 | 4.70 | 1.20 | 1.20 | 3.20 | 3.01 |
| 10 | 3.80 | 4.20 | 3.90 | 3.60 | 6.20 | 5.30 | 1.60 | 1.40 | 5.10 | 3.90 |
| 11 | 3.20 | 3.70 | 2.70 | 3.40 | 3.50 | 4.20 | 1.30 | 1.50 | 3.90 | [illegible] |
| 12 | 3.30 | 3.40 | 3.40 | 3.00 | 6.40 | 5.60 | 1.90 | 1.80 | 5.20 | 3.78 |
| 13 | 5.70 | 7.20 | 7.20 | 5.60 | 5.90 | 5.10 | 1.90 | 2.10 | 6.10 | 5.20 |
| 14 | 4.10 | 4.30 | 3.90 | 5.60 | 5.30 | 4.70 | 1.60 | 1.60 | 3.90 | 3.89 |
| 15 | 4.10 | 4.30 | 4.60 | 4.40 | 4.70 | 5.40 | 1.80 | 1.50 | 5.20 | 4.00 |
| 16 | 11.90 | 13.10 | 11.40 | 11.50 | 7.60 | 8.70 | 2.30 | 2.10 | 11.90 | 8.94 |
| 17 | 3.70 | 4.00 | 3.80 | 4.40 | 7.50 | 6.40 | 2.40 | 1.90 | 4.90 | 4.33 |

# APPENDIX C

## TABLE C.7

## RAW DATA RESULTS OF EEG RECORDINGS (BETA  ALL)

**Average Magnitudes of SMR per Site**

| ID# | s_c3 | s_c4 | s_cz | s_fz | s_o1 | s_o2 | s_p3 | s_p4 | s_pz | SMR_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.80 | 6.70 | 6.90 | 6.40 | 7.70 | 6.70 | 6.90 | 7.00 | 6.90 | 6.89 |
| 3 | 9.70 | 9.30 | 9.70 | 9.30 | 13.60 | 11.90 | 10.50 | 11.80 | 10.60 | 10.71 |
| 4 | 8.80 | 9.60 | 8.70 | 7.80 | 10.00 | 10.00 | 9.40 | 9.30 | 9.80 | 9.27 |
| 5 | 6.90 | 6.60 | 8.10 | 7.50 | 10.50 | 8.50 | 7.50 | 8.00 | 8.10 | 7.97 |
| 6 | 8.30 | 8.40 | 8.30 | 7.30 | 8.20 | 7.80 | 8.50 | 8.10 | 8.20 | 8.12 |
| 7 | 9.00 | 9.40 | 10.10 | 9.20 | 11.20 | 10.20 | 10.10 | 10.30 | 11.00 | 10.06 |
| 8 | 9.30 | 8.50 | 9.60 | 8.80 | 9.60 | 10.80 | 9.90 | 9.40 | 9.90 | 9.53 |
| 9 | 7.60 | 7.40 | 8.00 | 7.30 | 10.30 | 10.10 | 8.20 | 7.70 | 7.70 | 8.26 |
| 10 | 8.10 | 7.80 | 8.40 | 8.40 | 10.30 | 9.90 | 9.10 | 9.00 | 9.20 | 8.91 |
| 11 | 8.70 | 10.80 | 8.70 | 8.20 | 10.20 | 10.10 | 9.20 | 9.50 | 9.40 | 9.42 |
| 12 | 7.00 | 7.30 | 7.30 | 6.60 | 11.90 | 10.80 | 9.00 | 8.40 | 8.60 | 8.54 |
| 13 | 11.10 | 12.00 | 11.90 | 11.30 | 11.50 | 13.00 | 13.90 | 14.60 | 12.30 | 12.40 |
| 14 | 8.90 | 8.70 | 8.90 | 10.20 | 12.40 | 10.80 | 9.90 | 9.50 | 9.10 | 9.82 |
| 15 | 8.00 | 8.90 | 8.80 | 9.00 | 9.90 | 9.60 | 9.40 | 9.30 | 9.40 | 9.14 |
| 16 | 23.20 | 24.10 | 21.70 | 21.70 | 17.80 | 19.50 | 22.80 | 23.60 | 23.00 | 21.93 |
| 17 | 9.40 | 10.40 | 9.90 | 9.90 | 15.20 | 13.40 | 11.30 | 11.90 | 11.40 | 11.42 |

**Standard Deviations of SMR per Site**

| ID# | s.sd_c3 | s.sd_c4 | s.sd_cz | s.sd_fz | s.sd_o1 | s.sd_o2 | s.sd_p3 | s.sd_p4 | s.sd_pz | s.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.30 | 2.10 | 2.20 | 2.00 | 2.40 | 1.90 | 1.80 | 2.10 | 2.30 | 2.12 |
| 3 | 3.90 | 3.40 | 3.60 | 4.00 | 5.60 | 4.20 | 3.70 | 4.80 | 4.10 | 4.14 |
| 4 | 3.30 | 3.00 | 2.60 | 2.50 | 3.80 | 3.40 | 3.40 | 3.20 | 3.20 | 3.16 |
| 5 | 1.80 | 2.10 | 2.50 | 2.20 | 4.00 | 2.90 | 2.30 | 2.20 | 2.50 | 2.50 |
| 6 | 2.90 | 2.40 | 2.60 | 2.00 | 2.50 | 2.20 | 3.40 | 2.70 | 3.00 | 2.63 |
| 7 | 3.10 | 2.90 | 3.20 | 2.90 | 3.70 | 3.00 | 3.40 | 3.20 | 3.70 | 3.23 |
| 8 | 3.00 | 2.50 | 2.60 | 2.70 | 3.40 | 4.10 | 3.40 | 3.30 | 3.20 | 3.13 |
| 9 | 2.30 | 2.20 | 2.20 | 2.20 | 3.80 | 3.60 | 2.90 | 2.20 | 2.30 | 2.63 |
| 10 | 2.70 | 2.60 | 2.70 | 2.60 | 4.30 | 3.20 | 3.00 | 3.30 | 3.10 | 3.06 |
| 11 | 2.90 | 3.40 | 2.50 | 2.70 | 2.90 | 3.10 | 3.40 | 3.00 | 3.20 | 3.01 |
| 12 | 2.20 | 2.10 | 2.10 | 1.90 | 3.70 | 3.20 | 2.80 | 2.80 | 2.90 | 2.63 |
| 13 | 3.50 | 4.90 | 4.80 | 3.80 | 3.60 | 4.00 | 4.40 | 5.20 | 4.40 | 4.29 |
| 14 | 3.70 | 3.40 | 3.20 | 5.20 | 4.60 | 4.10 | 3.90 | 3.80 | 3.30 | 3.91 |
| 15 | 2.70 | 2.70 | 2.70 | 2.90 | 3.00 | 3.40 | 3.10 | 3.00 | 3.30 | 2.98 |
| 16 | 10.40 | 10.10 | 9.30 | 10.00 | 6.70 | 7.80 | 9.60 | 10.50 | 10.30 | 9.41 |
| 17 | 2.80 | 2.90 | 2.70 | 3.20 | 5.90 | 5.30 | 3.70 | 4.30 | 4.20 | 3.89 |

# APPENDIX C

## TABLE C.8

## RAW DATA RESULTS OF EEG RECORDINGS (EMG)

**Average Magnitudes of EMG per Site**

| ID# | em_c3 | em_c4 | em_cz | em_fz | em_o1 | em_o2 | em_p3 | em_p4 | em_pz | EMG_Av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12.00 | 12.30 | 12.50 | 11.60 | 12.80 | 11.20 | 12.00 | 12.30 | 11.90 | 12.07 |
| 3 | 17.40 | 16.80 | 17.10 | 16.30 | 21.60 | 19.20 | 18.00 | 19.30 | 17.60 | 18.14 |
| 4 | 14.10 | 15.00 | 14.30 | 14.10 | 15.60 | 16.00 | 14.70 | 14.70 | 14.90 | 14.82 |
| 5 | 12.00 | 12.10 | 14.60 | 14.20 | 18.30 | 14.90 | 13.20 | 13.60 | 13.80 | 14.08 |
| 6 | 15.10 | 16.30 | 15.40 | 13.50 | 15.20 | 15.20 | 16.00 | 15.80 | 15.40 | 15.32 |
| 7 | 17.30 | 18.60 | 19.40 | 17.40 | 20.90 | 19.40 | 19.60 | 20.50 | 22.00 | 19.46 |
| 8 | 15.70 | 15.20 | 16.60 | 15.50 | 16.00 | 18.40 | 16.60 | 15.90 | 16.90 | 16.31 |
| 9 | 13.10 | 12.90 | 13.90 | 12.60 | 17.10 | 16.60 | 14.00 | 13.00 | 13.00 | 14.02 |
| 10 | 14.90 | 14.70 | 15.40 | 15.20 | 17.50 | 17.30 | 17.10 | 16.40 | 16.80 | 16.14 |
| 11 | 14.90 | 17.30 | 14.80 | 14.30 | 17.20 | 18.10 | 15.50 | 16.20 | 15.90 | 16.02 |
| 12 | 13.30 | 14.20 | 13.90 | 12.70 | 23.80 | 20.90 | 17.90 | 16.50 | 17.00 | 16.69 |
| 13 | 20.60 | 21.50 | 21.90 | 20.70 | 21.50 | 23.00 | 23.90 | 24.00 | 21.00 | 22.01 |
| 14 | 15.40 | 15.00 | 15.60 | 17.30 | 19.30 | 17.40 | 16.80 | 16.30 | 15.20 | 16.48 |
| 15 | 15.20 | 17.20 | 16.90 | 17.80 | 17.90 | 19.20 | 16.90 | 18.10 | 18.00 | 17.47 |
| 16 | 36.10 | 38.60 | 32.80 | 32.80 | 27.40 | 29.60 | 36.30 | 36.00 | 34.90 | 33.83 |
| 17 | 16.80 | 18.30 | 17.90 | 18.50 | 24.70 | 22.20 | 18.80 | 19.30 | 19.00 | 19.50 |

**Standard Deviations of EMG per Site**

| ID# | em.sd_c3 | em.sd_c4 | em.sd_cz | em.sd_fz | em.sd_o1 | em.sd_o2 | em.sd_p3 | em.sd_p4 | em.sd_pz | em.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.30 | 1.20 | 1.30 | 1.20 | 1.30 | 1.20 | 1.20 | 1.10 | 1.20 | 1.22 |
| 3 | 1.20 | 1.50 | 1.50 | 1.30 | 1.80 | 2.60 | 1.50 | 1.60 | 1.40 | 1.60 |
| 4 | 1.40 | 1.50 | 1.50 | 1.40 | 1.60 | 2.20 | 1.30 | 1.40 | 1.30 | 1.51 |
| 5 | 2.20 | 1.70 | 1.70 | 3.60 | 6.80 | 3.90 | 2.50 | 2.10 | 2.00 | 2.94 |
| 6 | 1.50 | 1.60 | 1.50 | 1.50 | 1.50 | 1.70 | 1.80 | 1.60 | 1.70 | 1.60 |
| 7 | 1.60 | 1.60 | 1.40 | 1.90 | 2.50 | 2.90 | 1.60 | 1.60 | 1.50 | 1.84 |
| 8 | 1.30 | 1.80 | 1.40 | 1.40 | 3.00 | 3.40 | 1.50 | 1.70 | 1.40 | 1.88 |
| 9 | 1.10 | 1.30 | 1.20 | 1.50 | 1.80 | 1.60 | 1.30 | 1.30 | 1.30 | 1.38 |
| 10 | 1.70 | 1.50 | 1.50 | 1.80 | 2.30 | 2.60 | 1.60 | 1.60 | 2.00 | 1.84 |
| 11 | 2.00 | 1.70 | 1.80 | 1.60 | 2.40 | 2.30 | 2.00 | 1.60 | 1.70 | 1.90 |
| 12 | 1.40 | 1.40 | 1.40 | 1.30 | 2.90 | 2.70 | 1.90 | 1.80 | 1.80 | 1.84 |
| 13 | 1.90 | 2.60 | 1.90 | 2.30 | 9.30 | 5.90 | 2.50 | 2.40 | 1.90 | 3.41 |
| 14 | 1.30 | 1.20 | 1.20 | 1.20 | 1.90 | 2.00 | 1.60 | 1.30 | 1.40 | 1.46 |
| 15 | 2.00 | 1.80 | 1.80 | 2.10 | 2.80 | 2.40 | 1.50 | 1.70 | 1.70 | 1.98 |
| 16 | 2.30 | 2.90 | 2.10 | 1.70 | 1.70 | 2.20 | 1.70 | 1.90 | 1.60 | 2.01 |
| 17 | 2.20 | 2.10 | 2.10 | 1.90 | 3.20 | 2.50 | 2.00 | 1.60 | 1.90 | 2.17 |

# APPENDIX C

## TABLE C.9

## RAW DATA RESULTS OF EEG RECORDINGS (TOTAL EEG)

**Average Magnitudes of Total EEG per Site**

| ID# | to_c3 | to_c4 | to_cz | to_fz | to_o1 | to_o2 | to_p3 | to_p4 | to_pz | Total_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 89.80 | 90.60 | 96.80 | 84.70 | 96.90 | 86.60 | 91.00 | 93.40 | 93.80 | 91.51 |
| 3 | 107.20 | 109.10 | 110.90 | 102.50 | 139.70 | 125.90 | 116.10 | 124.80 | 114.40 | 116.73 |
| 4 | 100.50 | 103.90 | 111.10 | 102.10 | 109.50 | 112.40 | 106.50 | 103.40 | 112.20 | 106.84 |
| 5 | 95.60 | 96.30 | 115.30 | 109.80 | 127.80 | 115.30 | 100.50 | 106.70 | 109.50 | 108.53 |
| 6 | 104.70 | 120.10 | 115.30 | 92.70 | 111.90 | 118.60 | 116.20 | 122.70 | 121.00 | 113.69 |
| 7 | 118.30 | 127.40 | 139.20 | 122.30 | 137.10 | 126.20 | 127.20 | 136.60 | 144.70 | 131.00 |
| 8 | 96.10 | 100.60 | 115.80 | 99.00 | 97.30 | 107.40 | 103.70 | 100.20 | 109.20 | 103.26 |
| 9 | 88.30 | 89.10 | 101.10 | 88.60 | 98.20 | 96.90 | 86.00 | 81.50 | 85.20 | 90.54 |
| 10 | 94.30 | 94.60 | 104.30 | 96.40 | 107.90 | 119.50 | 103.10 | 109.80 | 112.20 | 104.68 |
| 11 | 105.50 | 112.30 | 108.70 | 103.00 | 123.60 | 132.20 | 118.60 | 128.10 | 125.60 | 117.51 |
| 12 | 92.70 | 101.10 | 102.30 | 93.80 | 174.60 | 150.90 | 131.20 | 119.80 | 121.70 | 120.90 |
| 13 | 121.50 | 124.70 | 132.30 | 124.10 | 123.30 | 129.30 | 132.90 | 131.10 | 121.20 | 126.71 |
| 14 | 100.30 | 97.80 | 108.80 | 100.40 | 130.40 | 123.60 | 105.60 | 102.00 | 100.40 | 107.70 |
| 15 | 102.90 | 112.40 | 114.90 | 110.80 | 127.80 | 138.20 | 113.20 | 121.60 | 122.70 | 118.28 |
| 16 | 164.30 | 178.70 | 155.10 | 150.10 | 136.40 | 144.70 | 167.30 | 165.80 | 162.90 | 158.37 |
| 17 | 113.70 | 117.60 | 125.30 | 115.00 | 136.80 | 129.70 | 120.60 | 117.40 | 125.50 | 122.40 |

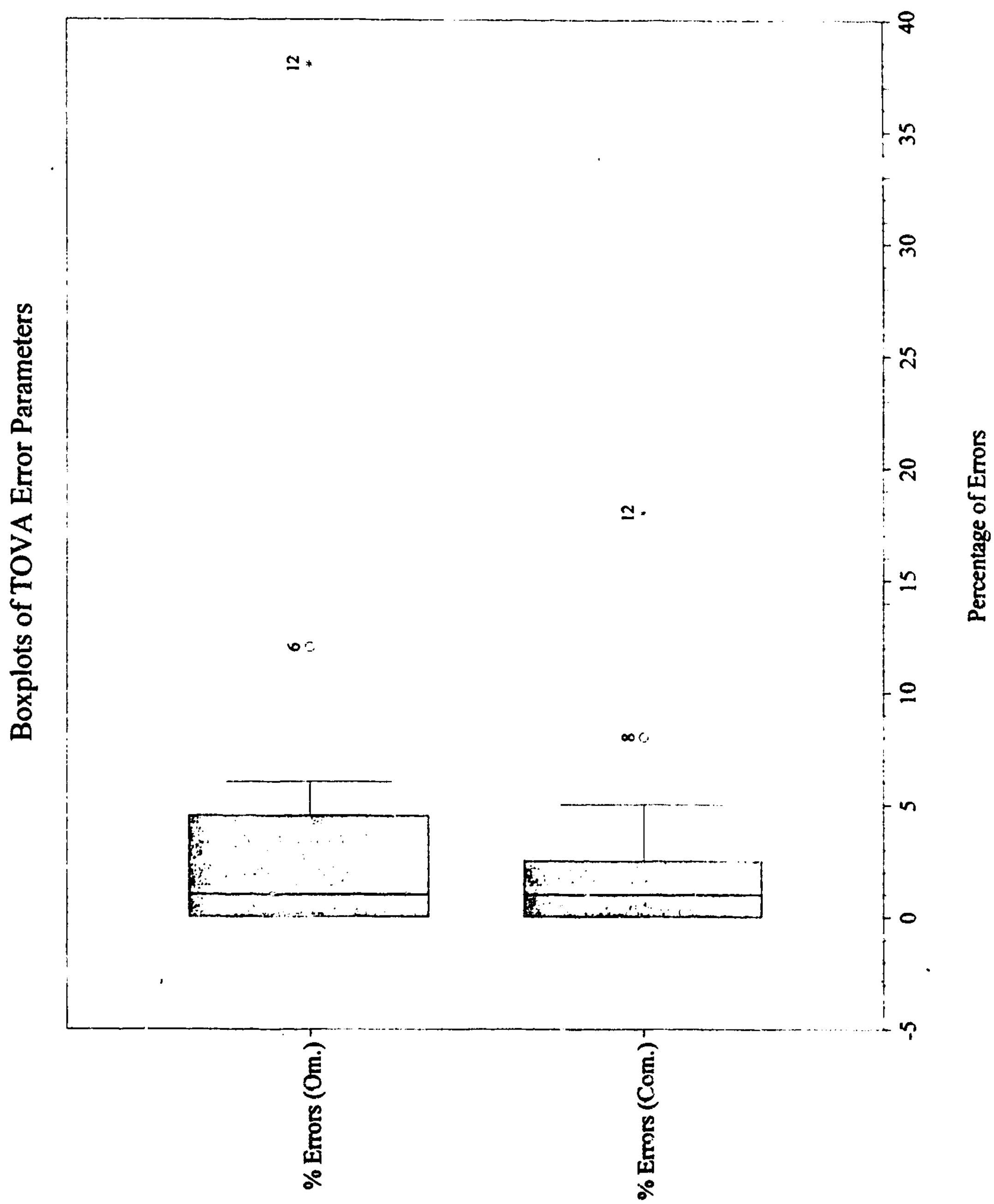
**Standard Deviations of Total EEG per Site**

| ID# | to.sd_c3 | to.sd_c4 | to.sd_cz | to.sd_fz | to.sd_o1 | to.sd_o2 | to.sd_p3 | to.sd_p4 | to.sd_pz | to.sd_av |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14.50 | 14.40 | 14.00 | 13.00 | 16.40 | 14.40 | 13.20 | 14.10 | 15.00 | 14.33 |
| 3 | 18.30 | 20.40 | 19.30 | 17.70 | 34.30 | 29.40 | 21.00 | 26.80 | 23.50 | 23.41 |
| 4 | 18.40 | 19.30 | 17.80 | 15.40 | 27.20 | 23.30 | 21.90 | 18.00 | 23.10 | 20.49 |
| 5 | 16.30 | 16.30 | 19.90 | 17.90 | 24.40 | 18.00 | 14.50 | 17.10 | 17.70 | 18.01 |
| 6 | 19.50 | 27.40 | 21.00 | 12.80 | 24.50 | 25.70 | 30.30 | 33.50 | 34.50 | 25.47 |
| 7 | 18.20 | 22.00 | 22.40 | 23.20 | 32.50 | 25.80 | 24.70 | 31.30 | 33.50 | 25.96 |
| 8 | 14.60 | 15.80 | 19.90 | 14.70 | 16.50 | 18.10 | 15.10 | 13.30 | 14.80 | 15.87 |
| 9 | 12.50 | 12.50 | 15.60 | 15.60 | 18.20 | 18.30 | 10.80 | 11.60 | 10.20 | 13.92 |
| 10 | 14.50 | 12.80 | 15.20 | 14.10 | 24.10 | 26.20 | 18.80 | 21.00 | 21.60 | 18.70 |
| 11 | 15.60 | 18.90 | 16.30 | 15.50 | 18.50 | 20.40 | 23.80 | 21.70 | 24.10 | 19.42 |
| 12 | 18.10 | 19.30 | 19.30 | 15.90 | 48.00 | 36.70 | 35.40 | 30.00 | 31.10 | 28.20 |
| 13 | 22.00 | 24.60 | 29.80 | 18.80 | 26.80 | 20.10 | 25.00 | 23.10 | 23.10 | 23.70 |
| 14 | 16.70 | 17.80 | 19.10 | 17.70 | 30.80 | 29.60 | 17.00 | 17.30 | 15.60 | 20.18 |
| 15 | 17.50 | 17.10 | 19.00 | 16.90 | 39.20 | 38.70 | 23.80 | 29.10 | 28.00 | 25.48 |
| 16 | 39.50 | 44.90 | 36.70 | 28.70 | 30.00 | 32.80 | 38.10 | 38.90 | 38.80 | 36.49 |
| 17 | 16.40 | 17.30 | 22.10 | 16.00 | 25.90 | 23.00 | 18.60 | 17.40 | 18.80 | 19.50 |

# Appendix D

Figure D.1

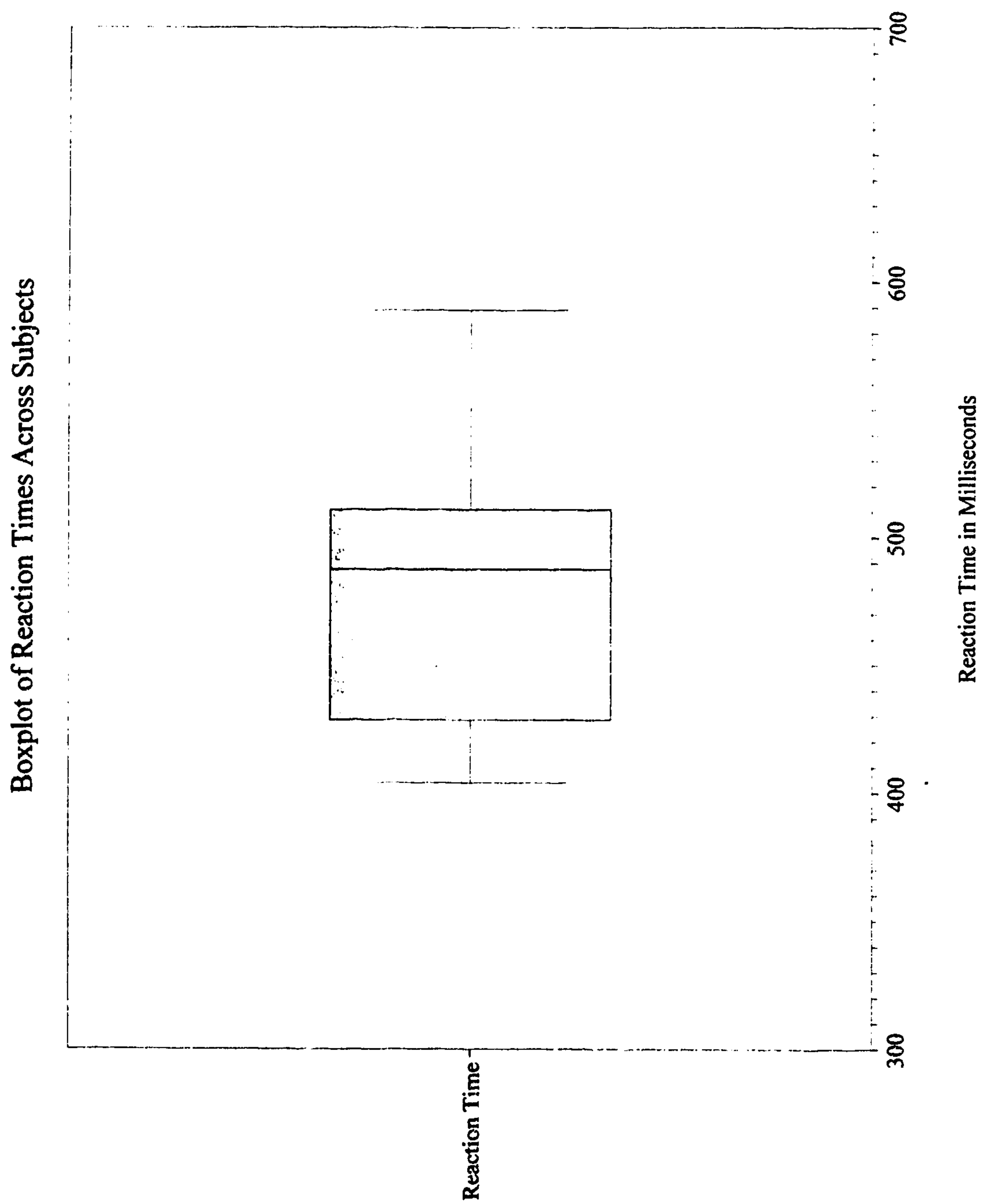
Boxplots of the T.O.V.A.™ Error Parameters of Omission and Commission



# APPENDIX D

FIGURE D.2

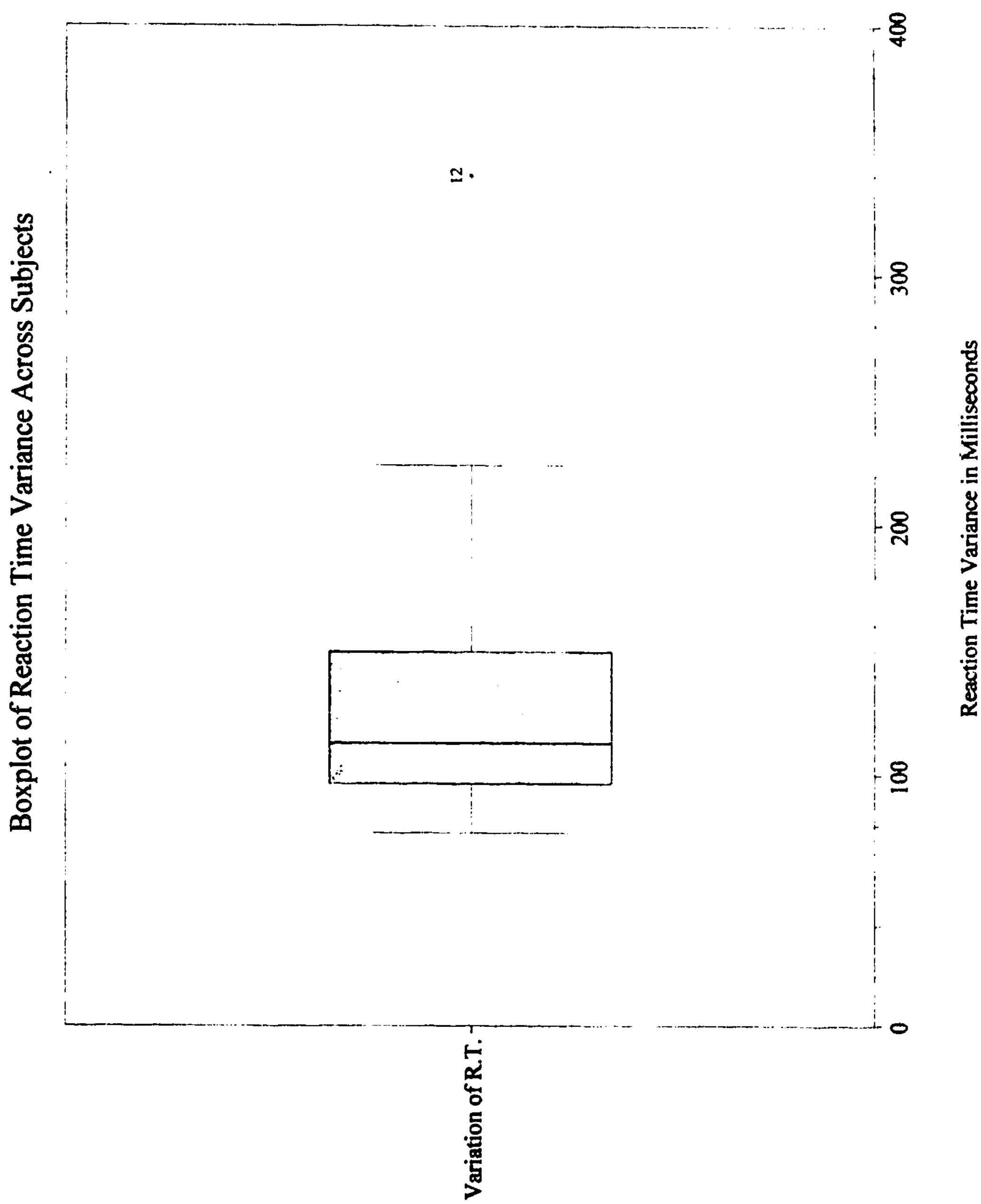
BOXPLOT OF THE T.O.V.A.™ PARAMETER OF REACTION TIME



# APPENDIX D

FIGURE D.3

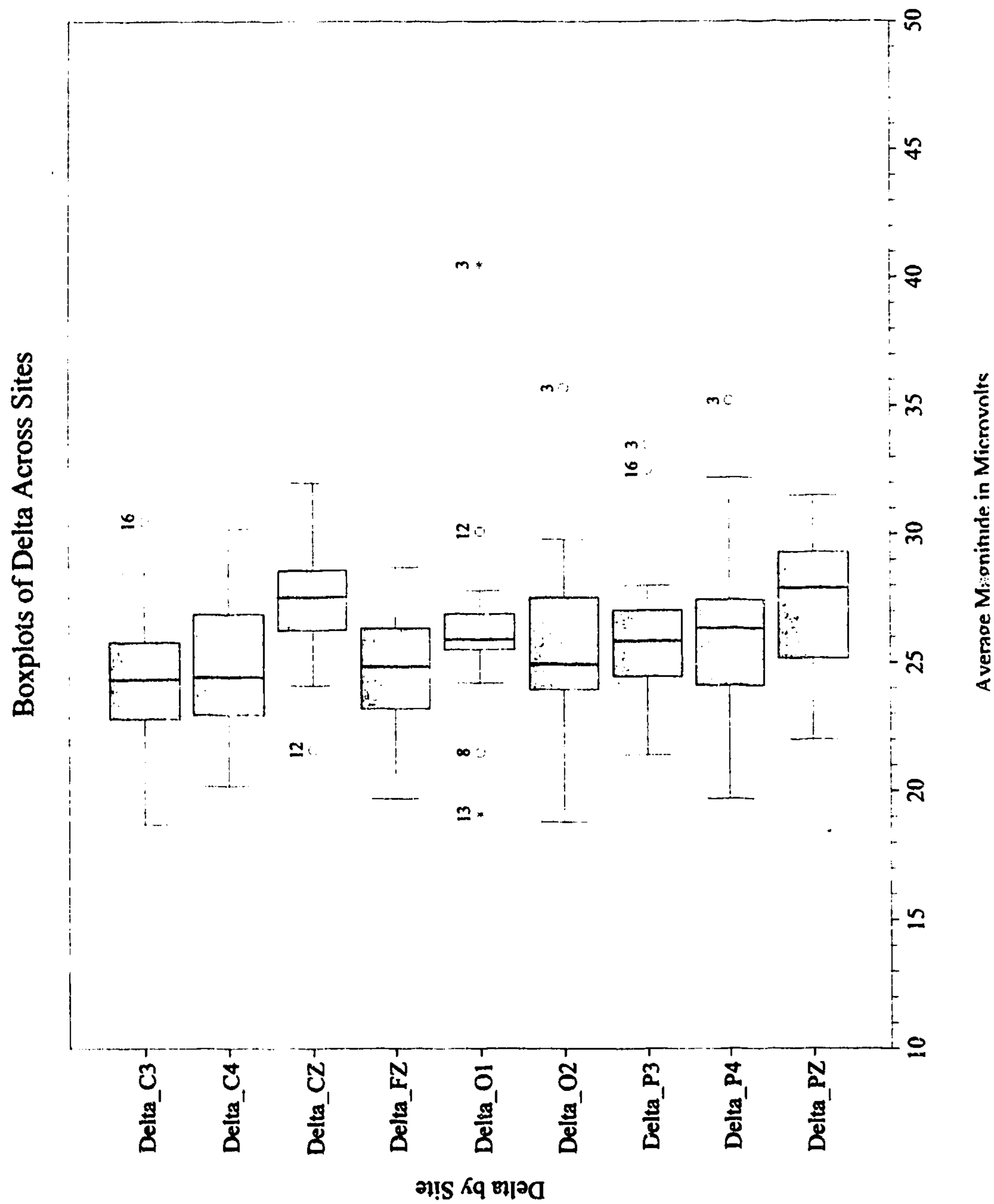
BOXPLOT OF THE T.O.V.A.™ PARAMETER OF REACTION TIME VARIABILITY



# APPENDIX E

FIGURE E.1

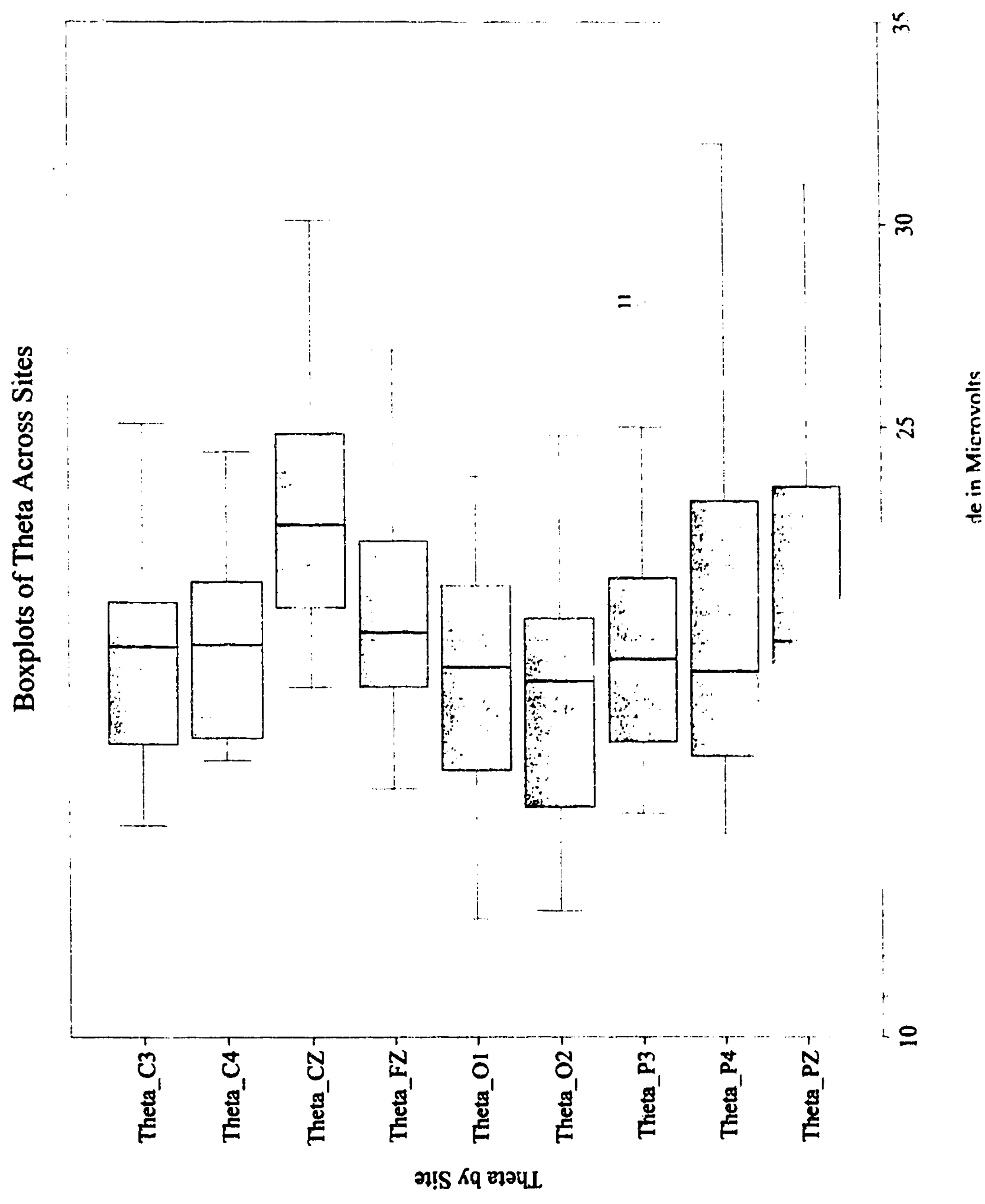
BOXPLOTS OF DELTA ACROSS SITES



**APPENDIX E**

FIGURE E.2

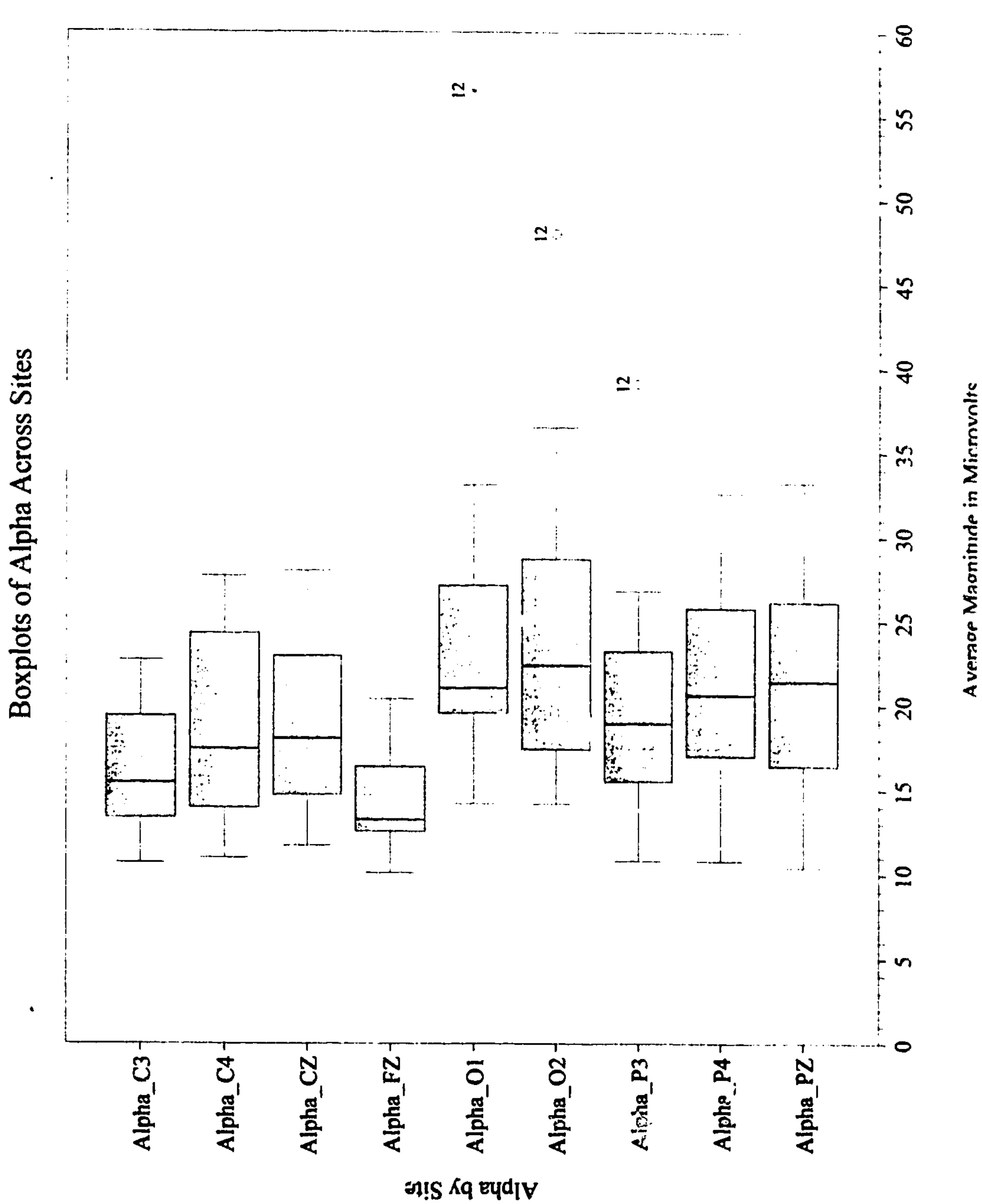
BOXPLOTS OF THETA ACROSS SITES



# Appendix E

Figure E.3

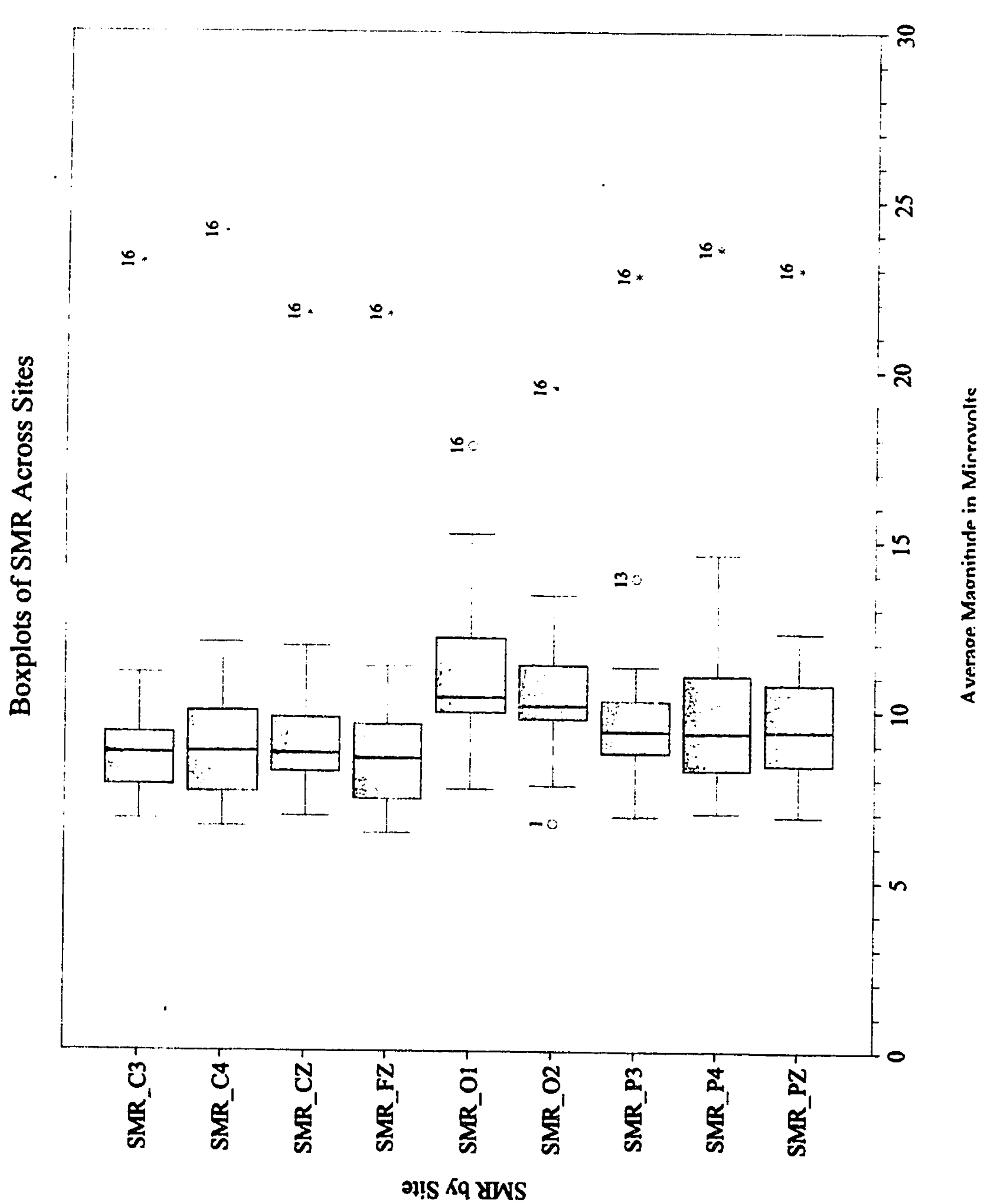
Boxplots of Alpha Across Sites



# APPENDIX E

FIGURE E.4

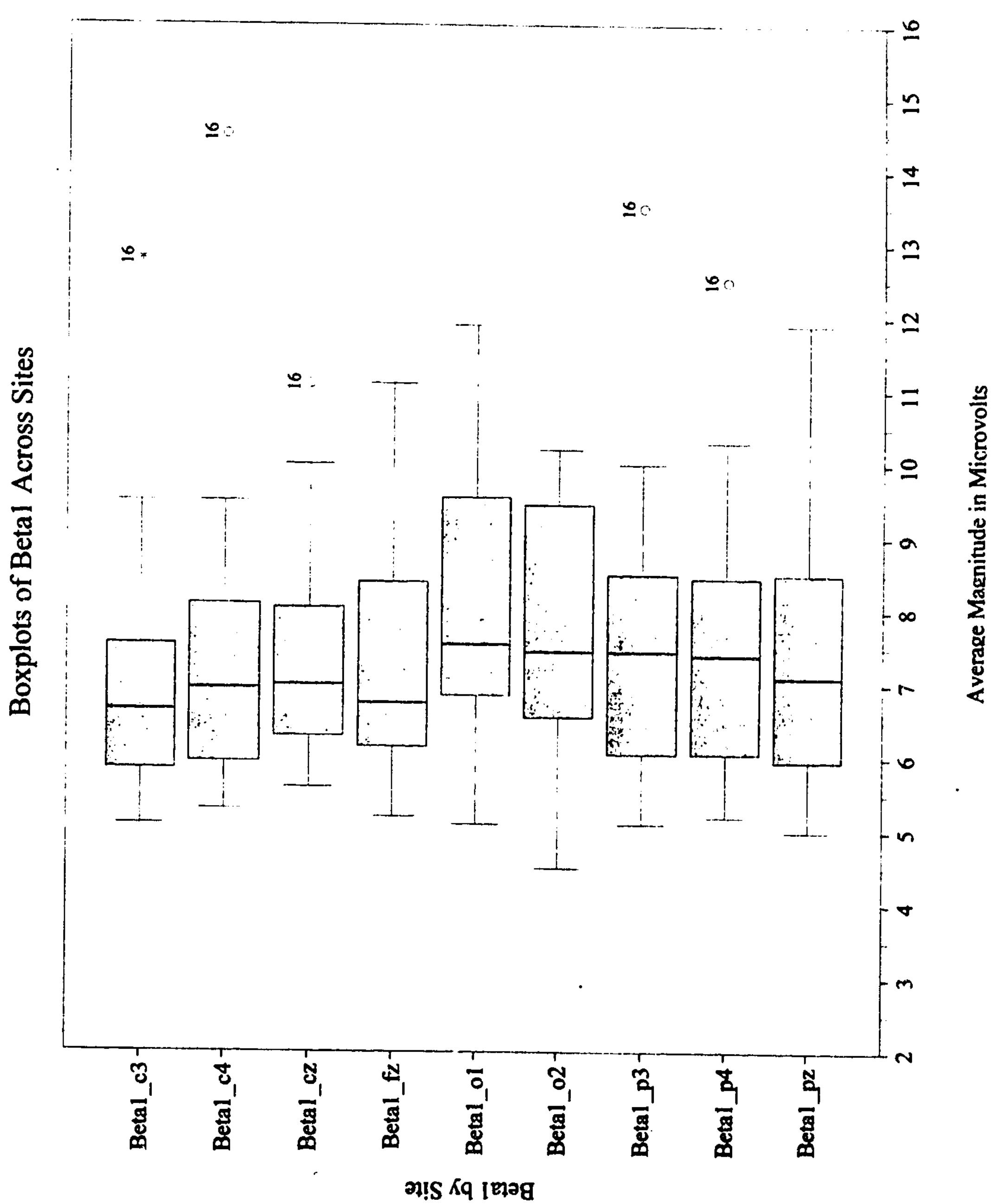
BOXPLOTS OF SMR ACROSS SITES



## Appendix E

FIGURE E.5

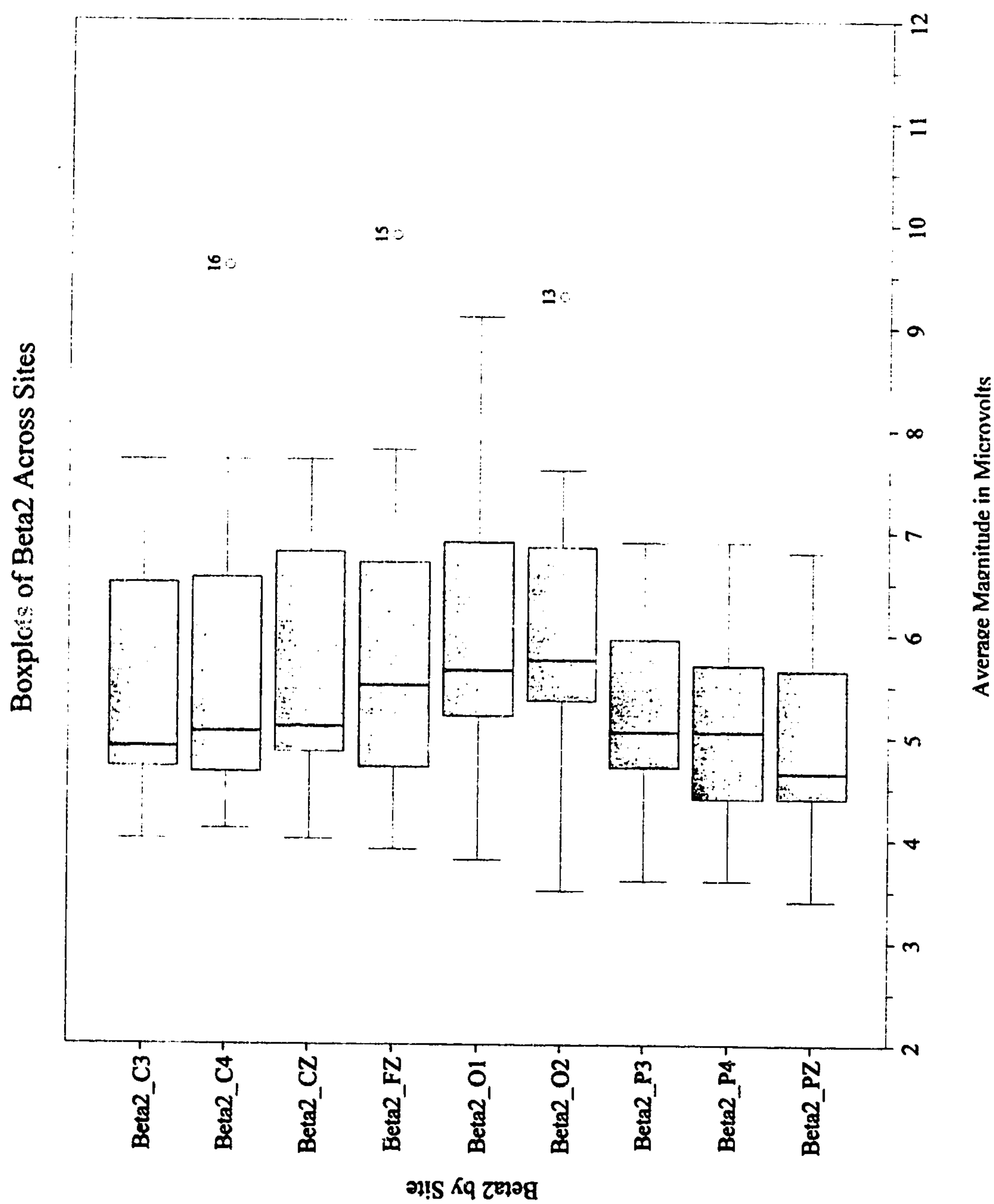
BOXPLOTS OF BETA1 ACROSS SITES



# APPENDIX E

FIGURE E.6

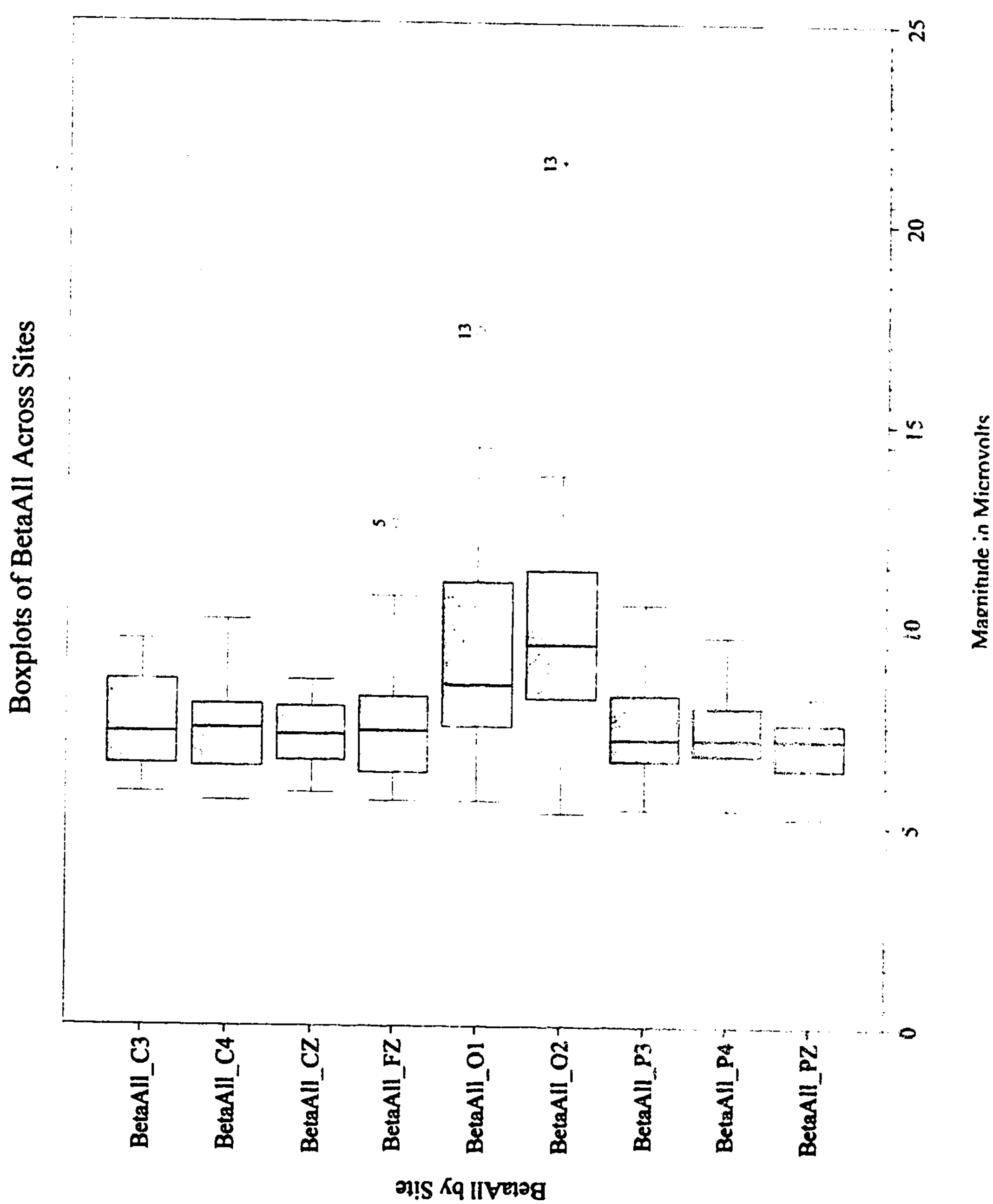
BOXPLOTS OF BETA2 ACROSS SITES



# APPENDIX E

FIGURE E.7

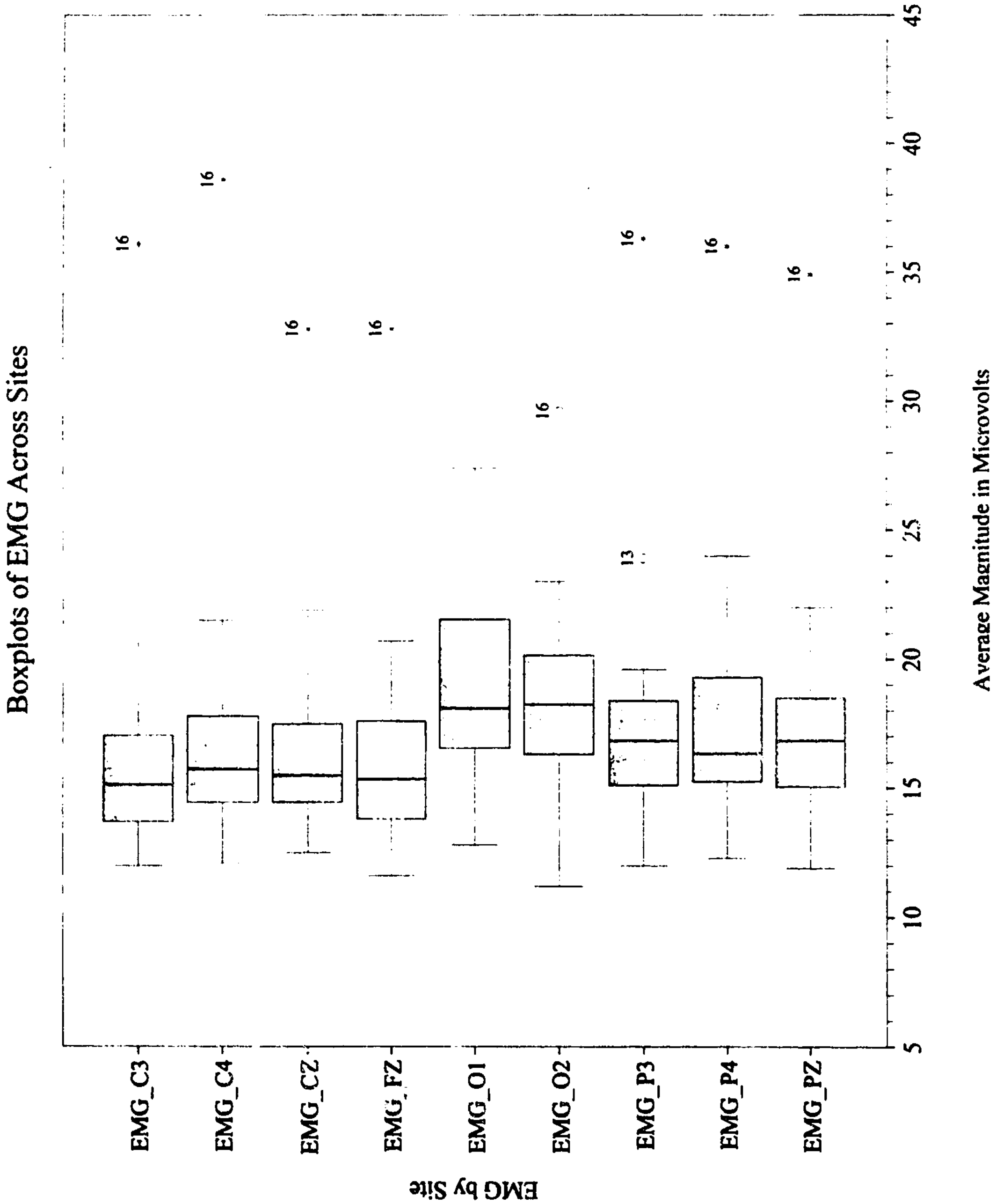
BOXPLOTS OF BETA_ALL ACROSS SITES



# Appendix E

Figure E.8

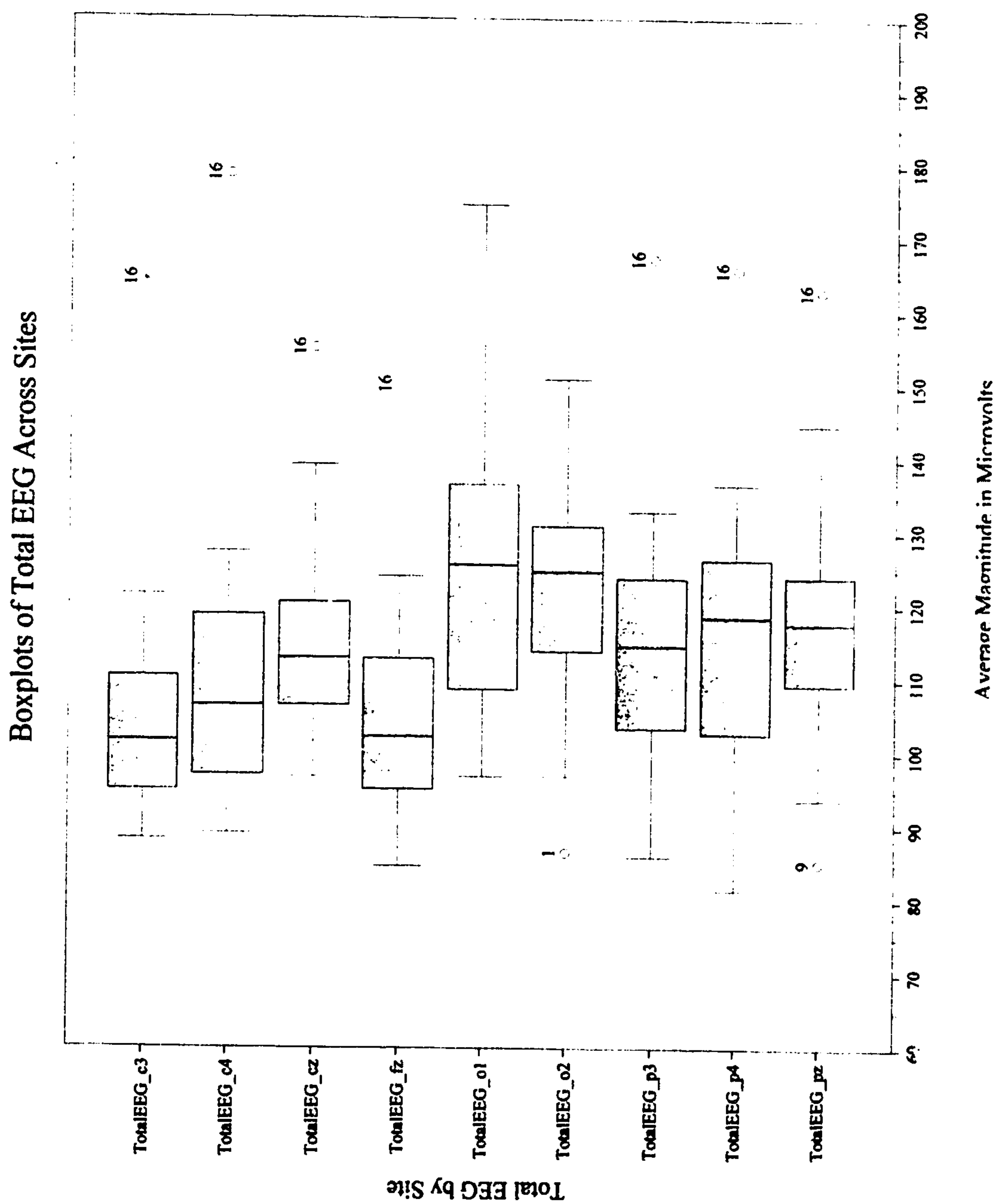
Boxplots of EMG Across Sites



# APPENDIX E

FIGURE E.9

BOXPLOTS OF TOTAL EEG ACROSS SITES



# APPENDIX F

## TABLE F.1

## CORRELATION TABLE FOR SITE C3

**Table F.1**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
**[SITE = C3]**

| | %o_err | %c_err | r.t. | r.t. var | d_c3 | th_c3 | a_c3 | s_c3 | b1_c3 | b2_c3 | bt_c3 | em_c3 | to_c3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_c3 | -0.53 | -0.65 | 0.30 | -0.52 | 1.00 | | | | | | | | |
| th_c3 | -0.36 | -0.57 | 0.15 | -0.38 | 0.69 | 1.00 | | | | | | | |
| a_c3 | 0.28 | 0.32 | -0.13 | 0.31 | -0.03 | 0.09 | 1.00 | | | | | | |
| s_c3 | -0.20 | -0.22 | 0.05 | -0.30 | 0.60 | 0.55 | 0.41 | 1.00 | | | | | |
| b1_c3 | -0.15 | -0.15 | -0.12 | -0.27 | 0.52 | 0.46 | 0.62 | 0.90 | 1.00 | | | | |
| b2_c3 | -0.21 | -0.13 | -0.10 | -0.21 | 0.43 | 0.32 | 0.73 | 0.66 | 0.85 | 1.00 | | | |
| bt_c3 | -0.29 | -0.24 | 0.18 | -0.15 | 0.19 | 0.31 | 0.49 | 0.31 | 0.43 | 0.59 | 1.00 | | |
| em_c3 | -0.19 | -0.20 | -0.01 | -0.29 | 0.59 | 0.53 | 0.49 | 0.99 | 0.95 | 0.74 | 0.36 | 1.00 | |
| to_c3 | -0.23 | -0.27 | 0.04 | -0.28 | 0.66 | 0.65 | 0.59 | 0.94 | 0.95 | 0.82 | 0.50 | 0.96 | 1.00 |

**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t.var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site C3 |
| th | = | Average Magnitude of Theta for site C3 |
| a | = | Average Magnitude of Alpha for site C3 |
| s | = | Average Magnitude of SMR for site C3 |
| b1 | = | Average Magnitude of Beta1 for site C3 |
| b2 | = | Average Magnitude of Beta2 for site C3 |
| bt | = | Average Magnitude of Beta_All for site C3 |
| em | = | Average Magnitude of EMG for site C3 |
| to | = | Average Magnitude of Total_EEG for site C3 |

# APPENDIX F

## TABLE F.2

## CORRELATION TABLE FOR SITE C4

**Table F.2**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
**[SITE = C4]**

| | %o_err | %c_err | r.t. | r.t. var | d_c4 | th_c4 | a_c4 | s_c4 | b1_c4 | b2_c4 | bt_c4 | em_c4 | to_c4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_c4 | -0.40 | -0.46 | 0.12 | -0.40 | 1.00 | | | | | | | | |
| th_c4 | -0.26 | -0.49 | 0.28 | -0.25 | 0.59 | 1.00 | | | | | | | |
| a_c4 | 0.33 | 0.24 | -0.04 | 0.36 | 0.16 | 0.23 | 1.00 | | | | | | |
| s_c4 | -0.20 | -0.23 | 0.13 | -0.26 | 0.49 | 0.51 | 0.56 | 1.00 | | | | | |
| b1_c4 | -0.09 | -0.10 | -0.04 | -0.17 | 0.56 | 0.37 | 0.72 | 0.89 | 1.00 | | | | |
| b2_c4 | -0.12 | -0.06 | 0.05 | -0.08 | 0.53 | 0.29 | 0.73 | 0.80 | 0.91 | 1.00 | | | |
| bt_c4 | -0.28 | -0.20 | 0.02 | -0.23 | 0.31 | 0.26 | 0.54 | 0.64 | 0.71 | 0.78 | 1.00 | | |
| em_c4 | -0.17 | -0.19 | 0.08 | -0.23 | 0.53 | 0.48 | 0.63 | 0.99 | 0.95 | 0.86 | 0.68 | 1.00 | |
| to_c4 | -0.12 | -0.19 | 0.09 | -0.14 | 0.60 | 0.57 | 0.75 | 0.93 | 0.96 | 0.90 | 0.72 | 0.96 | 1.00 |

**LEGEND**

%o_err = Percent Errors of Omission
%c_err = Percent Errors of Commission
r.t. = Reaction Time
r.t.var = Reaction Time Variability
d = Average Magnitude of Delta for site C4
th = Average Magnitude of Theta for site C4
a = Average Magnitude of Alpha for site C4
s = Average Magnitude of SMR for site C4
b1 = Average Magnitude of Beta1 for site C4
b2 = Average Magnitude of Beta2 for site C4
bt = Average Magnitude of Beta_All for site C4
em = Average Magnitude of EMG for site C4
to = Average Magnitude of Total_EEG for site C4

# Appendix F

## Table F.3

## Correlation Table for Site CZ

**Table F.3**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
[SITE = CZ]

| | %o_err | %c_err | r.t. | r.t. var | d_cz | th_cz | a_cz | s_cz | b1_cz | b2_cz | bt_cz | em_cz | to_cz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_cz | -0.55 | -0.57 | 0.13 | -0.44 | 1.00 | | | | | | | | |
| th_cz | -0.40 | -0.56 | 0.08 | -0.38 | 0.64 | 1.00 | | | | | | | |
| a_cz | 0.22 | 0.34 | -0.36 | 0.20 | -0.23 | -0.14 | 1.00 | | | | | | |
| s_cz | -0.24 | -0.23 | 0.01 | -0.32 | 0.19 | 0.31 | 0.25 | 1.00 | | | | | |
| b1_cz | -0.19 | -0.12 | -0.21 | -0.27 | 0.18 | 0.19 | 0.59 | 0.81 | 1.00 | | | | |
| b2_cz | -0.20 | -0.05 | -0.17 | -0.15 | 0.24 | 0.07 | 0.63 | 0.50 | 0.81 | 1.00 | | | |
| bt_cz | -0.25 | -0.21 | 0.11 | -0.07 | 0.30 | 0.22 | 0.42 | 0.36 | 0.54 | 0.64 | 1.00 | | |
| em_cz | -0.23 | -0.20 | -0.06 | -0.32 | 0.19 | 0.29 | 0.37 | 0.98 | 0.91 | 0.62 | 0.43 | 1.00 | |
| to_cz | -0.28 | -0.24 | -0.12 | -0.30 | 0.38 | 0.47 | 0.56 | 0.85 | 0.92 | 0.76 | 0.60 | 0.91 | 1.00 |

**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t.var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site CZ |
| th | = | Average Magnitude of Theta for site CZ |
| a | = | Average Magnitude of Alpha for site CZ |
| s | = | Average Magnitude of SMR for site CZ |
| b1 | = | Average Magnitude of Beta1 for site CZ |
| b2 | = | Average Magnitude of Beta2 for site CZ |
| bt | = | Average Magnitude of Beta_All for site CZ |
| em | = | Average Magnitude of EMG for site CZ |
| to | = | Average Magnitude of Total_EEG for site CZ |

# APPENDIX F

## TABLE F.4

## CORRELATION TABLE FOR SITE FZ

**Table F.4**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
**[SITE = FZ]**

| | %o_err | %c_err | r.t. | r.t. var | d_fz | th_fz | a_fz | s_fz | b1_fz | b2_fz | bt_fz | em_fz | to_fz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.73 | 0.59 | 0.26 | 1.00 | | | | | | | | | |
| d_fz | -0.63 | -0.54 | 0.12 | -0.42 | 1.00 | | | | | | | | |
| th_fz | -0.30 | -0.40 | -0.04 | -0.36 | 0.63 | 1.00 | | | | | | | |
| a_fz | 0.42 | 0.46 | -0.26 | 0.32 | 0.05 | 0.29 | 1.00 | | | | | | |
| s_fz | -0.27 | -0.25 | -0.01 | -0.25 | 0.46 | 0.40 | 0.41 | 1.00 | | | | | |
| b1_fz | -0.28 | -0.16 | -0.17 | -0.25 | 0.55 | 0.39 | 0.58 | 0.84 | 1.00 | | | | |
| b2_fz | -0.22 | 0.04 | -0.11 | -0.07 | 0.44 | 0.12 | 0.41 | 0.34 | 0.74 | 1.00 | | | |
| bt_fz | -0.33 | -0.17 | 0.03 | -0.09 | 0.34 | 0.42 | 0.25 | 0.12 | 0.40 | 0.53 | 1.00 | | |
| em_fz | -0.29 | -0.23 | -0.06 | -0.26 | 0.50 | 0.41 | 0.48 | 0.98 | 0.92 | 0.48 | 0.21 | 1.00 | |
| to_fz | -0.20 | -0.04 | 0.20 | -0.03 | 0.14 | 0.28 | 0.58 | 0.46 | 0.53 | 0.49 | 0.43 | 0.50 | 1.00 |

**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t.var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site FZ |
| th | = | Average Magnitude of Theta for site FZ |
| a | = | Average Magnitude of Alpha for site FZ |
| s | = | Average Magnitude of SMR for site FZ |
| b1 | = | Average Magnitude of Beta1 for site FZ |
| b2 | = | Average Magnitude of Beta2 for site FZ |
| bt | = | Average Magnitude of Beta_All for site FZ |
| em | = | Average Magnitude of EMG for site FZ |
| to | = | Average Magnitude of Total_EEG for site FZ |

# Appendix F

## Table F.5

## Correlation Table for Site O1

**Table F.5**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
[SITE = O1]

| | *%o_err* | *%c_err* | *r.t.* | *r.t. var* | *d_o1* | *th_o1* | *a_o1* | *s_o1* | *b1_o1* | *b2_o1* | *bt_o1* | *em_o1* | *to_o1* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_o1 | 0.29 | 0.03 | -0.19 | 0.05 | 1.00 | | | | | | | | |
| th_o1 | 0.16 | 0.04 | 0.13 | 0.19 | 0.51 | 1.00 | | | | | | | |
| a_o1 | 0.77 | 0.69 | -0.29 | 0.72 | 0.27 | 0.37 | 1.00 | | | | | | |
| s_o1 | -0.04 | -0.12 | -0.26 | -0.30 | 0.34 | 0.24 | 0.10 | 1.00 | | | | | |
| b1_o1 | 0.48 | 0.45 | -0.40 | 0.31 | 0.15 | 0.23 | 0.60 | 0.58 | 1.00 | | | | |
| b2_o1 | 0.29 | 0.37 | -0.39 | 0.25 | 0.20 | 0.17 | 0.43 | 0.30 | 0.81 | 1.00 | | | |
| bt_o1 | 0.07 | 0.22 | -0.28 | 0.09 | -0.35 | 0.12 | 0.13 | 0.14 | 0.60 | 0.93 | 1.00 | | |
| em_o1 | 0.20 | 0.13 | -0.36 | -0.05 | 0.30 | 0.27 | 0.34 | 0.93 | 0.84 | 0.57 | 0.37 | 1.00 | |
| to_o1 | 0.58 | 0.47 | -0.37 | 0.41 | 0.49 | 0.60 | 0.80 | 0.57 | 0.84 | 0.63 | 0.37 | 0.76 | 1.00 |

**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t.var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site O1 |
| th | = | Average Magnitude of Theta for site O1 |
| a | = | Average Magnitude of Alpha for site O1 |
| s | = | Average Magnitude of SMR for site O1 |
| b1 | = | Average Magnitude of Beta1 for site O1 |
| b2 | = | Average Magnitude of Beta2 for site O1 |
| bt | = | Average Magnitude of Beta_All for site O1 |
| em | = | Average Magnitude of EMG for site O1 |
| to | = | Average Magnitude of Total_EEG for site O1 |

# APPENDIX F

## TABLE F.6

## CORRELATION TABLE FOR SITE O2

**Table F.6**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
[SITE = O2]

| | %o_err | %c_err | r.t. | r.t. var | d_o2 | th_o2 | a_o2 | s_o2 | b1_o2 | b2_o2 | bt_o2 | em_o2 | to_o2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_o2 | 0.09 | -0.12 | 0.01 | -0.06 | 1.00 | | | | | | | | |
| th_o2 | 0.00 | -0.13 | 0.28 | 0.13 | 0.31 | 1.00 | | | | | | | |
| a_o2 | 0.63 | 0.56 | -0.15 | 0.66 | 0.14 | 0.18 | 1.00 | | | | | | |
| s_o2 | -0.08 | -0.08 | -0.20 | -0.30 | 0.21 | 0.08 | -0.08 | 1.00 | | | | | |
| b1_o2 | 0.31 | 0.37 | -0.32 | 0.20 | 0.05 | 0.10 | 0.46 | 0.61 | 1.00 | | | | |
| b2_o2 | 0.16 | 0.33 | -0.49 | 0.06 | -0.48 | -0.02 | 0.16 | 0.32 | 0.69 | 1.00 | | | |
| bt_o2 | -0.04 | 0.15 | -0.38 | -0.08 | -0.55 | -0.02 | -0.11 | 0.22 | 0.51 | 0.92 | 1.00 | | |
| em_o2 | 0.06 | 0.09 | -0.27 | -0.13 | 0.17 | 0.10 | 0.13 | 0.95 | 0.83 | 0.51 | 0.36 | 1.00 | |
| to_o2 | 0.41 | 0.36 | -0.29 | 0.30 | 0.29 | 0.41 | 0.67 | 0.57 | 0.87 | 0.51 | 0.29 | 0.75 | 1.00 |

**LEGEND**

%o_err = Percent Errors of Omission
%c_err = Percent Errors of Commission
r.t. = Reaction Time
r.t.var = Reaction Time Variability
d = Average Magnitude of Delta for site O2
th = Average Magnitude of Theta for site O2
a = Average Magnitude of Alpha for site O2
s = Average Magnitude of SMR for site O2
b1 = Average Magnitude of Beta1 for site O2
b2 = Average Magnitude of Beta2 for site O2
bt = Average Magnitude of Beta_All for site O2
em = Average Magnitude of EMG for site O2
to = Average Magnitude of Total_EEG for site O2

## APPENDIX F

TABLE F.7

CORRELATION TABLE FOR SITE P3

**Table F.7**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
[SITE = P3]

| | *%o_err* | *%c_err* | *r.t.* | *r.t. var* | *d_p3* | *th_p3* | *a_p3* | *s_p3* | *b1_p3* | *b2_p3* | *bt_p3* | *em_p3* | *to_p3* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_p3 | [illegible] | -0.22 | 0.08 | -0.19 | 1.00 | | | | | | | | |
| th_p3 | -0.12 | -0.29 | 0.23 | -0.09 | 0.52 | 1.00 | | | | | | | |
| a_p3 | 0.73 | 0.70 | -0.21 | 0.73 | 0.03 | 0.05 | 1.00 | | | | | | |
| s_p3 | -0.16 | -0.15 | -0.05 | -0.27 | 0.53 | 0.34 | 0.22 | 1.00 | | | | | |
| b1_p3 | 0.10 | 0.09 | -0.23 | -0.03 | 0.42 | 0.28 | 0.51 | 0.87 | 1.00 | | | | |
| b2_p3 | 0.02 | 0.03 | -0.26 | -0.04 | 0.22 | 0.27 | 0.56 | 0.69 | 0.80 | 1.00 | | | |
| bt_p3 | 0.01 | 0.05 | -0.07 | 0.07 | -0.01 | 0.34 | 0.37 | 0.34 | 0.41 | 0.65 | 1.00 | | |
| em_p3 | -0.07 | -0.07 | -0.12 | -0.19 | 0.51 | 0.33 | 0.34 | 0.98 | 0.95 | 0.75 | 0.37 | 1.00 | |
| to_p3 | 0.19 | 0.13 | -0.10 | 0.10 | 0.57 | 0.51 | 0.61 | 0.85 | 0.92 | 0.81 | 0.51 | 0.90 | 1.00 |

**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t.var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site P3 |
| th | = | Average Magnitude of Theta for site P3 |
| a | = | Average Magnitude of Alpha for site P3 |
| s | = | Average Magnitude of SMR for site P3 |
| b1 | = | Average Magnitude of Beta1 for site P3 |
| b2 | = | Average Magnitude of Beta2 for site P3 |
| bt | = | Average Magnitude of Beta_All for site P3 |
| em | = | Average Magnitude of EMG for site P3 |
| to | = | Average Magnitude of Total_EEG for site P3 |

# APPENDIX F

## TABLE F.8

## CORRELATION TABLE FOR SITE P4

**Table F.8**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
[SITE = P4]

| | %o_err | %c_err | r.t. | r.t. var | d_p4 | th_p4 | a_p4 | s_p4 | b1_p4 | b2_p4 | bt_p4 | em_p4 | to_p4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_p4 | -0.02 | -0.14 | 0.05 | -0.12 | 1.00 | | | | | | | | |
| th_p4 | -0.18 | -0.34 | 0.37 | -0.08 | 0.50 | 1.00 | | | | | | | |
| a_p4 | 0.53 | 0.42 | -0.08 | 0.59 | 0.22 | 0.17 | 1.00 | | | | | | |
| s_p4 | -0.20 | -0.20 | -0.03 | -0.32 | 0.45 | 0.21 | 0.16 | 1.00 | | | | | |
| b1_p4 | 0.02 | 0.02 | -0.19 | -0.06 | 0.48 | 0.20 | 0.60 | 0.79 | 1.00 | | | | |
| b2_p4 | 0.01 | 0.05 | -0.28 | -0.03 | 0.09 | 0.06 | 0.63 | 0.61 | 0.84 | 1.00 | | | |
| bt_p4 | -0.08 | 0.02 | -0.30 | -0.07 | 0.15 | 0.21 | 0.47 | 0.49 | 0.59 | 0.75 | 1.00 | | |
| em_p4 | -0.13 | -0.13 | -0.09 | -0.24 | 0.48 | 0.21 | 0.32 | 0.98 | 0.90 | 0.72 | 0.55 | 1.00 | |
| to_p4 | 0.04 | -0.04 | -0.01 | 0.00 | 0.66 | 0.51 | 0.63 | 0.79 | 0.91 | 0.73 | 0.62 | 0.87 | 1.00 |

**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t. var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site O1 |
| th | = | Average Magnitude of Theta for site O1 |
| a | = | Average Magnitude of Alpha for site O1 |
| s | = | Average Magnitude of SMR for site O1 |
| b1 | = | Average Magnitude of Beta1 for site O1 |
| b2 | = | Average Magnitude of Beta2 for site O1 |
| bt | = | Average Magnitude of Beta_All for site O1 |
| em | = | Average Magnitude of EMG for site O1 |
| to | = | Average Magnitude of Total_EEG for site O1 |

# APPENDIX F

## TABLE F.9

## CORRELATION TABLE FOR SITE PZ

**Table F.9**

**Pearson Product Moment Correlations: EEG Bands and TOVA Parameters**
[SITE = PZ]

| | %o_err | %c_err | r.t. | r.t. var | d_pz | th_pz | a_pz | s_pz | b1_pz | b2_pz | bt_pz | em_pz | to_pz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %o_err | 1.00 | | | | | | | | | | | | |
| %c_err | 0.88 | 1.00 | | | | | | | | | | | |
| r.t. | -0.27 | -0.38 | 1.00 | | | | | | | | | | |
| r.t. var | 0.88 | 0.79 | 0.06 | 1.00 | | | | | | | | | |
| d_pz | -0.17 | -0.27 | 0.18 | -0.18 | 1.00 | | | | | | | | |
| th_pz | -0.21 | -0.34 | 0.31 | -0.12 | 0.64 | 1.00 | | | | | | | |
| a_pz | 0.53 | 0.49 | -0.14 | 0.60 | 0.19 | 0.05 | 1.00 | | | | | | |
| s_pz | -0.18 | -0.18 | -0.02 | -0.29 | 0.44 | 0.25 | 0.20 | 1.00 | | | | | |
| b1_pz | 0.07 | 0.09 | -0.25 | -0.03 | 0.38 | 0.23 | 0.62 | 0.74 | 1.00 | | | | |
| b2_pz | -0.05 | -0.02 | -0.28 | -0.08 | 0.26 | 0.21 | 0.65 | 0.52 | 0.84 | 1.00 | | | |
| bt_pz | 0.07 | 0.06 | -0.19 | 0.12 | 0.28 | 0.26 | 0.52 | 0.26 | 0.48 | 0.64 | 1.00 | | |
| em_pz | -0.10 | -0.09 | -0.11 | -0.21 | 0.45 | 0.26 | 0.37 | 0.97 | 0.89 | 0.67 | 0.36 | 1.00 | |
| to_pz | 0.04 | -0.01 | -0.03 | 0.02 | 0.65 | 0.52 | 0.64 | 0.79 | 0.89 | 0.77 | 0.56 | 0.88 | 1.00 |

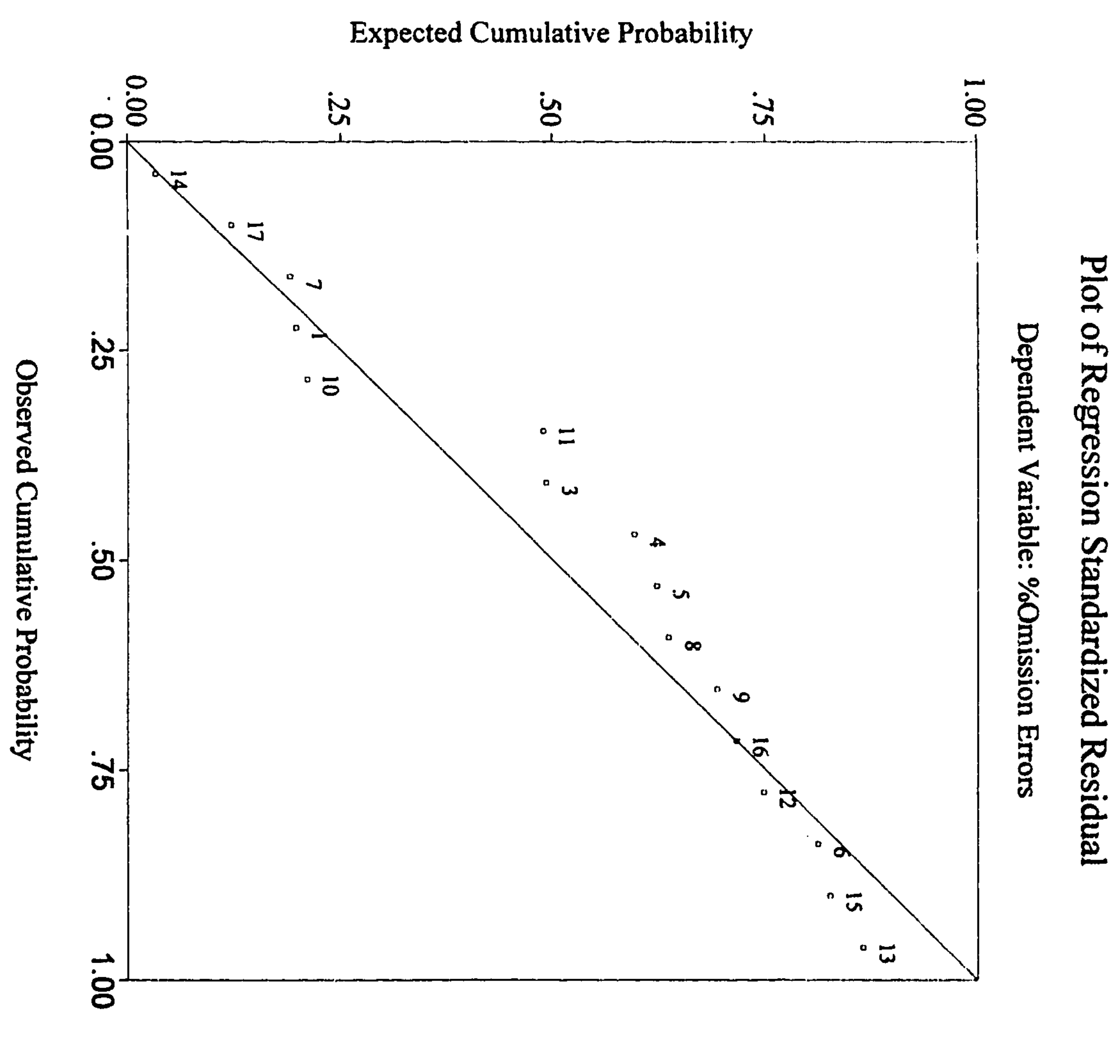
**LEGEND**

| | | |
|---|---|---|
| %o_err | = | Percent Errors of Omission |
| %c_err | = | Percent Errors of Commission |
| r.t. | = | Reaction Time |
| r.t.var | = | Reaction Time Variability |
| d | = | Average Magnitude of Delta for site PZ |
| th | = | Average Magnitude of Theta for site PZ |
| a | = | Average Magnitude of Alpha for site PZ |
| s | = | Average Magnitude of SMR for site PZ |
| b1 | = | Average Magnitude of Beta1 for site PZ |
| b2 | = | Average Magnitude of Beta2 for site PZ |
| bt | = | Average Magnitude of Beta_All for site PZ |
| em | = | Average Magnitude of EMG for site PZ |
| to | = | Average Magnitude of Total_EEG for site PZ |

## APPENDIX G

FIGURE G.1

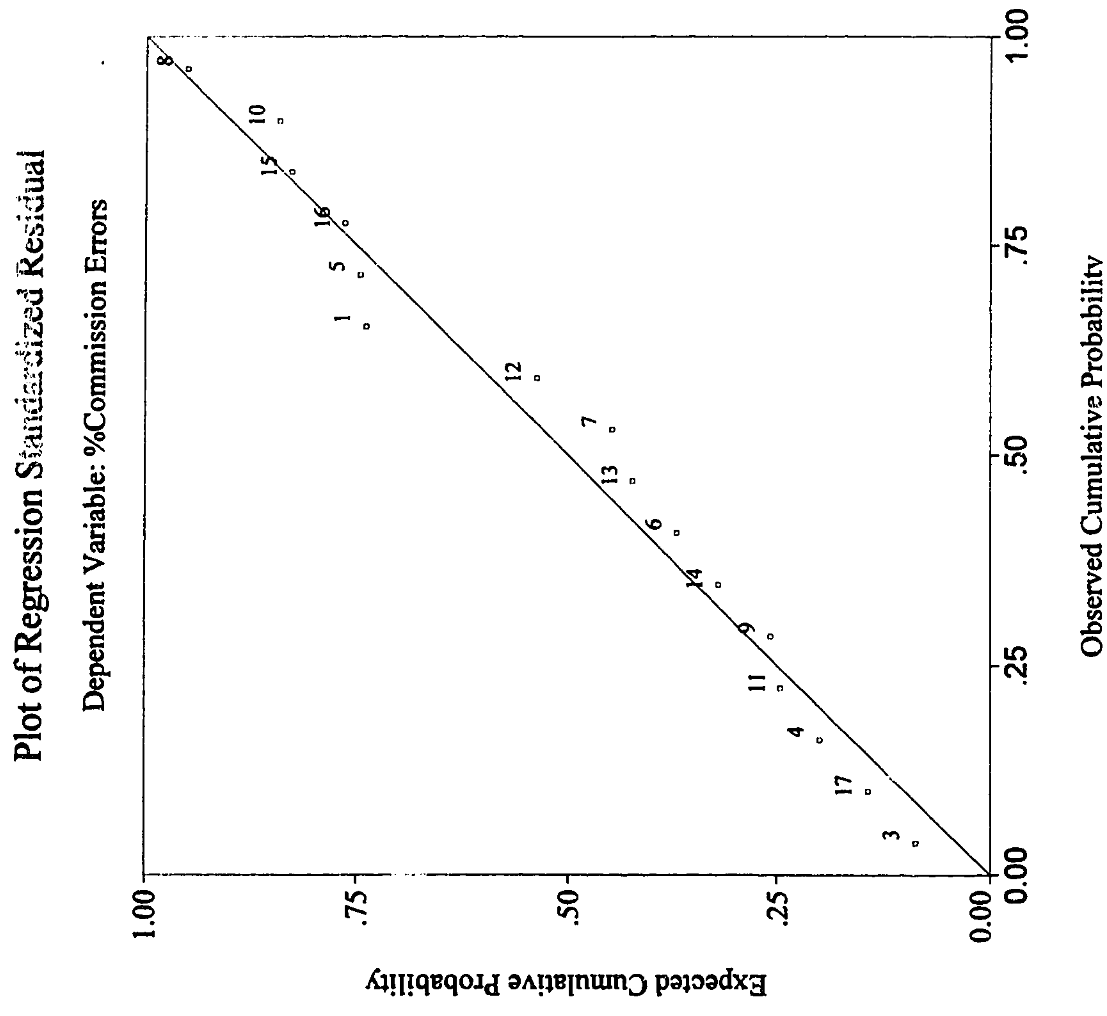
NORMAL PROBABILITY DISTRIBUTION PLOT FOR % ERRORS OF OMISSION



## Appendix G

Figure G.2

Normal Probability Distribution Plot for % Errors of Commission



# APPENDIX H

## MULTIPLE REGRESSION EQUATION 4.1

## PREDICTION OF %ERRORS OF OMISSION FROM AVERAGE EEG BAND MAGNITUDES

Dependent Variable = %E_ERR (%Errors of Omission)

| | |
|---|---|
| Multiple R: | 0.94858 |
| R Square ($R^2$): | 0.89980 |
| Adjusted R Square: | 0.86337 |
| Standard Error: | 3.52736 |

-------------------- Analysis of Variance --------------------

| | DF | Sum of Squares | Mean Square |
|---|---|---|---|
| Regression | 4 | 1229.07260 | 307.26815 |
| Residual | 11 | 136.86490 | 12.44226 |

F = 24.69552  Signif F = 0.0000

------------------ Variables in the Equation ------------------

| Variable | B | SE B | Beta | T | Sig T |
|---|---|---|---|---|---|
| A_O1 | 1.488062 | 0.240565 | 1.577913 | 6.186 | 0.0001 |
| A_O2 | –1.164851 | 0.281680 | –1.120178 | –4.135 | 0.0017 |
| D_FZ | –2.834239 | 0.533369 | –0.708503 | –5.314 | 0.0002 |
| D_PZ | 1.071214 | 0.389375 | 0.328142 | 2.751 | 0.0189 |
| (Constant) | 37.292361 | 12.502890 | 2.983000 | 0.0125 | |

---------------------- Residuals Statistics ----------------------

| | Min | Max | Mean | Std Dev | N |
|---|---|---|---|---|---|
| *PRED | –3.8886 | 35.6510 | 4.4375 | 9.0520 | 16 |
| *RESID | –6.4400 | 3.8886 | 0.0000 | 3.0207 | 16 |
| *ZPRED | –0.9198 | 3.4483 | 0.0000 | 1.0000 | 16 |
| *ZRESID | –1.8257 | 1.1024 | 0.0000 | 0.8563 | 16 |

Total Cases = 36

# APPENDIX H

REGRESSION EQUATION 4.2

PREDICTION OF %ERRORS OF COMMISSION FROM EEG BAND MAGNITUDES

Dependent Variable = %C_ERR (%Errors of Commission)

| | |
|---|---|
| Multiple R: | 0.95098 |
| R Square ($R^2$): | 0.90437 |
| Adjusted R Square: | 0.86959 |
| Standard Error: | 1.67168 |

-------------------- Analysis of Variance --------------------

| | DF | Sum of Squares | Mean Square |
|---|---|---|---|
| Regression | 4 | 290.69797 | 72.67449 |
| Residual | 11 | 30.73953 | 2.79450 |

F = 26.00623   Signif F = 0.0000

------------------ Variables in the Equation ------------------

| Variable | B | SE B | Beta | T | Sig T |
|---|---|---|---|---|---|
| A_C3 | −1.343925 | 0.242953 | −1.060908 | −5.532 | 0.0002 |
| A_P3 | 1.423372 | 0.158547 | 2.084231 | 8.978 | 0.0000 |
| A_P4 | −0.560021 | 0.144329 | −0.741592 | −3.880 | 0.0026 |
| B2_O2 | 0.995369 | 0.425837 | 0.288254 | 2.337 | 0.0393 |
| (Constant) | 1.664124 | 2.311185 | 0.720 | 0.4865 | |

---------------------- Residuals Statistics ----------------------

| | Min | Max | Mean | Std Dev | N |
|---|---|---|---|---|---|
| *PRED | −1.2051 | 17.8413 | 2.6875 | 4.4023 | 16 |
| *RESID | −2.2641 | 2.7714 | 0.0000 | 1.4315 | 16 |
| *ZPRED | −0.8842 | 3.4423 | 0.0000 | 1.0000 | 16 |
| *ZRESID | −1.3544 | 1.6578 | 0.0000 | 0.8563 | 16 |

Total Cases = 36