Over twenty-five years of publishing research articles related to the theory and applications of psychological type and the Myers-Briggs Type Indicator® instrument.

65

Journal of Psychological Type®

Issue 5 | NOV 05

> EEG measurements show that psychological types have an identifiable underlying physiological substrate that differs for each type.

Relationship Between EEG and Psychological Type

Peter C. Gram, Bruce R. Dunn, and Diana Ellis
University of West Florida

ABSTRACT

This study investigated the relationship between Myers-Briggs Type Indicator® (MBTI®) personality types and cortical activity. Cortical activity was measured by recording eyes-open EEG across bandwidths from 1 Hz to 39 Hz at 19 cortical sites. The findings in the alpha bandwidth were generally congruent with Eysenck's biological theory of extraversion–introversion. Furthermore, participants showed specific and different patterns of cortical activity associated with each of the other MBTI dimensions in the various bandwidths.

INTRODUCTION

During the "decade of the brain," a major research thrust was an attempt to link psychological or behavioral phenomena to their underlying physiological substrates. This included attempts to connect various personality constructs with physiological measures, particularly the features of the brain's electrophysiologic or EEG activity. EEG has been used by researchers because it is extremely reliable within subjects (e.g., Pollock, Schneider, & Lyness, 1991, obtained intrasubject correlations greater than .84 after 4.5 months) and can be used to measure personality traits and cognitive style differences (Dunn & Reddix, 1991). Because of the influence of Eysenck's (1967, 1976) biologically based personality theory, most of the research in this area has concentrated on the relationship between EEG activity and the constructs of extraversion and introversion (E–I). Interestingly, most of the EEG research has primarily based the measurement of extraversion on Eysenck's Personality Inventory (EPI; Eysenck & Eysenck, 1964).

Based on the work of Jung (1921/1971), Eysenck and Rachman (1965) defined extraversion as one end of a bipolar dimension characterized by low levels of cortical arousal. People high on this trait are sociable and impulsive. Introversion is characterized by high

Published by the Center for Applications of Psychological Type CAPT®
Thomas G. Carskadon, Ph.D., Editor

levels of cortical arousal and caution. Extraverts seek conditions that bring arousal levels up to a comfortable degree of stimulation, whereas introverts generally avoid arousing situations. Therefore, according to Eysenck, introverts should display lower amplitude, higher frequency baseline EEG patterns (typically beta > 12 Hz), and extraverts should display higher-amplitude, lower-frequency activity (typically alpha bandwidth 8–12 Hz) in their baseline EEG records.

Gale and Edwards (1986) reported numerous studies that yielded equivocal support for Eysenck's theory. The majority of researchers obtained results supporting Eysenck's theory that extraverts generate more alpha bandwidth activity (and thus are assumed to be less aroused) than introverts (e.g., S. M. Baker's unpublished dissertation cited in Gale, 1981; Gale, Coles, & Blaydon, 1969; Rösler, 1975). However, others found less alpha bandwidth production (more arousal) associated with extraversion, which is the opposite of the theory's prediction (e.g., Broadhurst & Glass, 1969; Mundy-Castle, 1955; Shagass & Kerenyi, 1958). Still other researchers found no differences in alpha bandwidth production (e.g., Gale, Coles, Kline, & Penfold, 1971; Henry & Knott, 1941; Strelau & Terelak, 1974). Surprisingly, few studies reported differences in the beta bandwidth (> 12 Hz), primarily because few collected any beta activity. (See Gale & Edwards, 1986). These data are carefully examined in the present study.

Extraverts seek conditions that bring arousal levels up to a comfortable degree of stimulation, whereas Introverts generally avoid arousing situations.

Gale (1983) concluded that the ambiguity in the alpha bandwidth activity results across studies was caused by variations in experimental conditions. Furthermore, he recommended that personality should be measured under conditions that provide the greatest sensitivity for detecting differences, i.e., conditions requiring a medium level of cognitive load (e.g., arousal). The results of a study by Wilson and Languis (1989) reinforced this recommendation. They recorded EEG activity in both eyes-open and eyes-closed baseline conditions. In the eyes-open condition, introverts had lower alpha (8–13 Hz) amplitude than extraverts, supporting Eysenck's theory. The eyes-closed data yielded the opposite pattern. However, because the eyes-open baseline condition may require a greater cognitive load than an eyes-closed baseline (Gale, 1983), the implication is that the eyes-open condition would be a better index of the E–I dichotomy than an eyes-closed situation. That is, with their eyes open, participants would be more compelled to attend to their surroundings.

As suggested earlier, one reason for the lack of clear support for Eysenck's theory may be methodologically based. One possibility is that the E–I dichotomy based on the MBTI measure may be a more valid index of Eysenck's notion of arousal than the more widely studied EPI (Eysenck & Rachman, 1965). Another problem in studying E–I has been a lack of standardization in the placement of reference electrodes. Some researchers have used a bipolar reference (Deakin & Exley, 1979; Montgomery, 1975; Morris & Gale, 1974), whereas others have used a unipolar reference such as linked ears (e.g., Stenberg, 1992). Dunn (1985) and Pfurtscheller (1988) have pointed out that the placement of reference electrodes makes a difference in the interpretation of recorded EEG data.

The use of bipolar recordings can cause problems in assessing bilateral hemispheric activity. The differential amplifiers that are used to record EEG readings measure the difference between two electrodes. Consequently, it is possible for two left hemispheric bipolar sites to be producing 50 +v of alpha bandwidth activity each and homologous bipolar sites on the right hemisphere to be generating 10 +v and 5 +v, respectively. The difference between left hemispheric production of alpha bandwidth activity would be recorded as 0 +v and the right hemispheric production of alpha bandwidth activity as 5 +v. Obviously, the interpretation that the right hemisphere produced more alpha bandwidth activity would be erroneous. A better method is to use a neutral unipolar reference site, such as linked ears or linked mastoids, that records little, if any, brain activity.

Another possible methodological problem is that different researchers do not agree on a specific standard of "EEG arousal." Some early researchers (e.g., Jaspar, Solomon, & Bradley, 1938) defined "slow" as 2–7 Hz, whereas others (e.g., Ulett, Gleser, Winokur, & Lawler, 1953), labeled 3–7 Hz as "very slow," and "fast" activity as 16–24 Hz. Newman (1985) used 13–30 Hz for "fast wave beta." Finally, few researchers have reported studies of frequencies faster than 30 Hz (e.g., DeFrance & Sheer, 1988). We used the currently accepted frequency bandwidths: delta (1–3 Hz), theta (4–7 Hz), and alpha bandwidth (8–12 Hz). Based on Dunn, Hartigan, and Mikulas (1999), we divided the beta bandwidth into three segments: beta 1 (13–25 Hz), beta 2 (26–30 Hz), and beta 3 (31–39 Hz).

A final problem is related to the placement and number of recording electrodes used by different researchers. Most researchers have adopted the international 10/20 electrode placement system that has 19 active recording sites (Jaspar, 1958). However, researchers who have examined personality constructs typically use only some of these sites. For example, Pawlik and Cattell (1965) used sites that approximated the current standard frontal cortical sites (Fp1, Fp2, F3, F4), the temporal sites (T3, T4), the parietal sites (P3, P4), and the occipital sites (O1 and O2). Fenton and Scotton (1967) used only F3 and a point between O1 and O2. Winter, Broadhurst and Glass (1972) used four pairs of bipolar recording sites (C4/P4, P4/O2, C3/P3, and P3/O1). The solutions to these methodological problems are discussed below.

Because of the EEG personality literature's emphasis on E–I, the examination of the relation of EEG correlates to other personality constructs has been neglected. One of the more popular personality indicators, the Myers-Briggs Type Indicator (MBTI) tool, not only measures a preference for E–I, but also contains dichotomies that measure Sensing–Intuition (S–N), Thinking–Feeling (T–F), and Judging–Perceiving (J–P) (Myers & McCaulley, 1985).

Lyons (1985) appears to be the only other researcher who has investigated the relationship between other dimensions of the MBTI measure and EEG, as the Wilson and Languis (1989, 1990) studies concentrated only on the MBTI's E–I dichotomy. Lyons analyzed EEG data for 20 participants who had taken the MBTI instrument but calculated only a rough measure of hemispheric processing (laterality). Although Lyons reported hemispheric differences (a correlation between the T–F scale and right hemispheric processing), she used only bipolar recording sites (P3/T3 and P4/T4). As explained above, the use of bipolar recordings makes any definitive statement about differential hemispheric processing impossible.

The present study addressed the methodological problems inherent in most EEG-based personality studies, namely a) the dependence on the EPI rather than on other measures of E–I, like the MBTI measure; b) the reliance of some studies on bipolar, rather than unipolar recordings, the latter of which use a relatively "neutral" reference electrode; c) an absence of standard bandwidths used to reflect a person's state of cortical arousal; and d) a lack of sufficient recording sites to provide a complete picture of cortical activity related to various personality traits. Like Wilson and Languis (1989, 1990), we handled these four methodological problems by using the MBTI instrument as our index of personality differences, by using a unipolar (linked ears) reference, by analyzing the data into standard frequency bandwidths ranging from 1 to 39 Hz, and by using all 19 active recording sites of the standard 10–20 system (Jaspar, 1958).

This study also examined possible relationships between the EEG and the other subscales of the MBTI instrument. It is hoped that these descriptive data will generate interest in further investigations of relationships between the EEG and these other Jungian personality dichotomies.

METHOD AND PROCEDURE

Thirty-five students (29 females and 6 males) ranging in age from 18 to 36 years (median = 24) volunteered to participate. All were recruited from introductory psychology classes and received extra credit as well as their results on the MBTI instrument.

Volunteers reported individually to the laboratory, where their baseline EEGs were recorded as they looked at a blank screen for 5 minutes. All were asked to gaze at the screen in front of them but to be aware of their surroundings. They were also told to avoid making excessive muscle and eye movements. All participants were run in the afternoon (from 12:30 to 4:00). The surroundings and instructions added a small cognitive load as suggested by Gale (1983). During the last 2 minutes of the recording period, eyes-open baseline EEG data were collected. Eleven of the participants were part of a pilot study of memory. However, collection of their baseline EEG occurred before the memory task. After the EEG data were recorded, each participant completed the MBTI Form G instrument.

EEG data were recorded from 19 brain sites according to the standard international 10/20 system, using a fitted nylon ECI Electro-cap™. A PDP 11/73 computer-based brain-imaging system controlled the data collection. The EEG signals were amplified using a gain of 50,000 via 21 Grass Model JP511 series preamplifiers, with the 1/2 amplitude low-frequency cutoff set at 0.1 Hz and the 1/2 amplitude high-frequency cutoff set at 100 Hz, with the 60 Hz notch filter engaged. Eye movements and blinks were recorded from an electrode placed on the infraorbital ridge of the left eye, which was referred to another electrode placed above the right eye of the supraorbital ridge. All data were edited off-line for eye movement and muscle artifacts. Only 5% of the EEG records were rejected. All active brain sites were referred to linked ears, and the midline frontal-parietal site (Fpz) served as the subjects' ground. EEG records were sampled at 256 Hz.

> *"Overall, these results suggest that people who prefer Intuition probably do considerably more internal processing in a sparse environment."*

RESULTS

EEG Data. Each artifact-free EEG record was subjected to a Fast Fourier Transform (FFT), producing amplitude spectra using a Hanning window. The resultant amplitude data were then converted into six frequency bandwidths (i.e., delta: 1–3 Hz; theta: 4–7 Hz; alpha: 8–12 Hz; beta 1: 13–25 Hz; beta 2: 26–30 Hz; beta 3: 31–39 Hz).

MBTI preferences were determined for males and females based on the standard scoring system for Form G. **Table 1 (see page 37)** shows the type distribution of our total sample.

Although separate bandwidths (e.g., alpha 8–12 Hz) were studied, the relationship of each individual frequency from a given bandwidth (e.g., 10 Hz activity) to a given personality dichotomy also was investigated. That is, frequency was treated as an independent variable. Using the alpha bandwidth as an example, this would result in a 2 (personality type) by 19 (electrode site) by 6 (individual frequencies; 8–12 Hz) mixed design. The groups' EEG data across frequency and recording site were then compared using separate MANOVAs for each personality dichotomy.

All the MANOVAs showed that individual frequencies did not contribute to any statistically significant interaction, i.e., only the entire bandwidth did. This left the significant two-way (personality type by recording site) interactions to directly answer the questions posed by this study. Wilks' λ was used to determine the overall significance of each MANOVA. Differences between personality types were tested at each separate recording electrode using Tukey's contrasts at a .05 level of significance to determine which personality types were significantly different from each other (for a given frequency bandwidth) at each of the 19 recording sites. For brevity, the means for these significant contrasts between site means are not reported here but are available from the authors.

Extraversion–Introversion Dichotomy. The MANOVAs for the Extraversion–Introversion dichotomy yielded significant personality by electrode site interactions for the theta, alpha, beta 1, beta 2, and beta 3 bandwidths, Wilks' λ = .72, $F(18, 148) = 3.21$, $p < .0009$; Wilks' λ = .76, $F(18, 412) = 7.13$, $p < .0009$; Wilks' λ = .62, $F(18, 148) = 5.13$, $p < .0009$; Wilks' λ = .63, $F(13, 278) = 9.00$, $p < .0009$, respectively. No other main effects or interactions were significant.

Figure 1 (see page 38) contains the distributions of the significant cortical sites of a given bandwidth for the Extraversion–Introversion personality dichotomy based on the Tukey *post hoc* tests. None of the individual Tukey tests were significant in the theta bandwidth. The upper left section shows the distribution of the alpha bandwidth data. Extraverts produced significantly greater alpha mean amplitude (showed less internal arousal) than did Introverts at frontal and midline frontal sites *F*3 and *Fz*; central and midline central sites C3, C4, and Cz; parietal and midline parietal sites P3, P4, and Pz; temporal site T6; and occipital sites O1 and O2. As predicted by Eysenck's (1967) theory, Extraverts produced significantly less amplitude in the faster frequencies of beta 2 and beta 3 bandwidth (at the bottom of **Figure 1**, again indicating less cortical arousal), but the activity pattern was mixed for beta 1 bandwidth (discussed below).

Introverts showed more amplitude in the beta 2 bandwidth for the frontal sites *F*8 and *Fz*; central sites C3, C4, and Cz; and temporal site T5. Introverts also showed more amplitude in the beta 3 bandwidth for the frontal site *F*8; parietal site P4; and temporal sites T4, T5, and T6.

Table 1. MBTI® Type Distribution of Total Sample.

The Sixteen Complete Types

ISTJ *n* = 1 (2.9%) + + +	ISFJ *n* = 2 (5.7%) + + + + + +	INFJ *n* = 0 (0.0%)	INTJ *n* = 2 (5.7%) + + + + + +
ISTP *n* = 1 (2.9%) + + +	ISFP *n* = 1 (2.9%) + + +	INFP *n* = 2 (5.7%) + + + + + +	INTP *n* = 2 (5.7%) + + + + + +
ESTP *n* = 1 (2.9%) + + +	ESFP *n* = 1 (2.9%) + + +	ENFP *n* = 5 (14.3%) + + + + + + + + + + + + + +	ENTP *n* = 2 (5.7%) + + + + + +
ESTJ *n* = 3 (8.6%) + + + + + + + + +	ESFJ *n* = 5 (14.3%) + + + + + + + + + + + + + +	ENFJ *n* = 5 (14.3%) + + + + + + + + + + + + + +	ENTJ *n* = 2 (5.7%) + + + + + +

Dichotomous Preferences

E	*n* = 24	(68.6%)
I	*n* = 11	(31.4%)
S	*n* = 15	(42.9%)
N	*n* = 20	(57.1%)
T	*n* = 14	(40.0%)
F	*n* = 21	(60.0%)
J	*n* = 20	(57.1%)
P	*n* = 15	(42.9%)

Pairs and Temperaments

IJ	*n* = 5	(14.3%)
IP	*n* = 6	(17.1%)
EP	*n* = 9	(25.7%)
EJ	*n* = 15	(42.9%)
ST	*n* = 6	(17.1%)
SF	*n* = 9	(25.7%)
NF	*n* = 12	(34.3%)
NT	*n* = 8	(22.9%)
SJ	*n* = 11	(31.4%)
SP	*n* = 4	(11.4%)
NP	*n* = 11	(31.4%)
NJ	*n* = 9	(25.7%)
TJ	*n* = 8	(22.9%)
TP	*n* = 6	(17.1%)
FP	*n* = 9	(25.7%)
FJ	*n* = 12	(34.3%)
IN	*n* = 6	(17.1%)
EN	*n* = 14	(40.0%)
IS	*n* = 5	(14.3%)
ES	*n* = 10	(28.6%)
ET	*n* = 8	(22.9%)
EF	*n* = 16	(45.7%)
IF	*n* = 5	(14.3%)
IT	*n* = 6	(17.1%)

Jungian Types (E)

	n	%	*Index*
E–TJ	5	14.3	n.a.
E–FJ	10	28.6	n.a.
ES–P	2	5.7	n.a.
EN–P	7	20.0	n.a.

Jungian Types (I)

	n	%	*Index*
I–TP	3	8.6	n.a.
I–FP	3	8.6	n.a.
IS–J	3	8.6	n.a.
IN–J	2	5.7	n.a.

Dominant Types

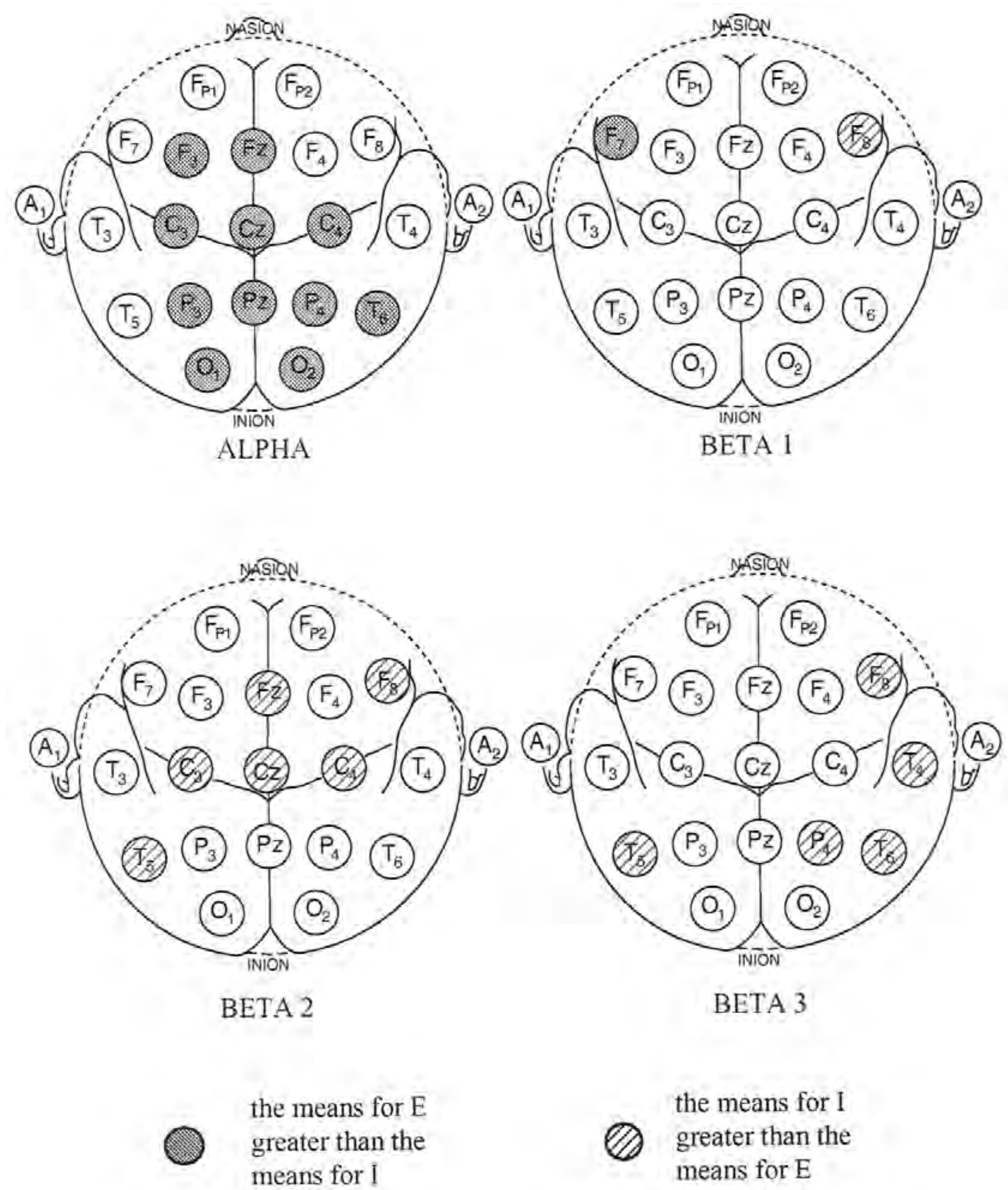
	n	%	*Index*
Dt. T	8	22.9	n.a.
Dt. F	13	37.1	n.a.
Dt. S	5	14.3	n.a.
Dt. N	9	25.7	n.a.

***N* = 35 + = 1% of *N* *I* = Selection Ratio Index **p*<.05 ***p*<.01 ****p*<.001**

Peter C. Gram, Bruce R. Dunn, and Diana Ellis, Relationship Between EEG and Psychological Type.

Figure 1. Extraversion–Introversion

Significant site differences based on a Tukey at .05 for the different bandwidths for the personality dichotomy of Extraversion–Introversion (E–I).



Peter C. Gram, Bruce R. Dunn, and Diana Ellis, Relationship Between EEG and Psychological Type.

The mixed activity pattern of the beta 1 bandwidth revealed that Introverts had greater mean amplitude than Extraverts at the *F*8 frontal site, whereas Extraverts had greater mean amplitude at frontal site *F*7. With the exception of the beta 1 data, the analyses of the bandwidth activity of alpha and beta 2 and beta 3 data support Eysenck's theory and will be addressed in the discussion.

Sensing–Intuition Dichotomy. The MANOVAs for the Sensing–Intuition dichotomy resulted in significant personality by electrode site interactions for the theta, beta 1, beta 2, and beta 3 bandwidths: Wilks' $\lambda = .74$, $F(18, 115) = 2.07$, $p < .01$; Wilks' $\lambda = .71$, $F(18, 379) = 8.65$, $p < .0009$; Wilks; $\lambda = .57$, $F(18, 181) = 7.47$, $p < .0009$, and Wilks' $\lambda = .58$, $F(18, 278) = 11.18$, $p < .0009$, respectively. No other main effects or interactions were significant.

FIGURE 2 (SEE PAGE 40) contains the distributions of the significant cortical sites of a given bandwidth for the S–N personality dichotomy based on the Tukey *post hoc* tests. The upper left portion shows that at every site, individuals who preferred Sensing produced greater mean theta amplitude than did individuals who preferred Intuition. It should be recalled that theta activity occurs during sleep and states of deep relaxation. Thus, the theta data suggest that with little environmental stimulation (i.e., the EEG recording room), people preferring Sensing had little to process, hence generating high levels of theta activity.

The pattern differed in the beta 1 bandwidth, for which Intuitive types produced greater mean amplitude than Sensing types at frontal sites *F*p1, *F*3, *F*4, and *F*z; central sites C3, C4, and Cz; parietal sites P3 and P4; temporal site T6; and occipital sites O1 and O2. Ns also produced greater mean amplitude in beta 2 and beta 3 bandwidths, but only at site T4. These latter results are probably spurious, since these were not found in other sites. Overall, these results suggest that people who prefer Intuition probably do considerably more internal processing in a sparse environment.

Thinking–Feeling Dichotomy. Significant personality by electrode site interactions for the delta, theta, alpha, beta 1, beta 2, and beta 3 bandwidths were obtained by MANOVAs for the Thinking–Feeling dichotomy: Wilks' $\lambda = .59$, $F(18, 82) = 3.20$, $p < .0009$; Wilks' $\lambda = .50$, $F(18, 115) = 6.35$, $p < .0009$; Wilks' $\lambda = .58$, $F(18, 148) = 5.88$, $p < .0009$; Wilks' $\lambda = .56$, $F(18, 412) = 17.87$, $p < .0009$; Wilks' $\lambda = .55$, $F(18, 148) = 6.82$, $p < .0009$; and Wilks' $\lambda = .55$, $F(18, 278) = 12.48$, $p < .0009$, respectively. No other main effects or interactions were significant. Although the personality type by recording sites interactions were significant for delta bandwidth, none of the individual *post hoc* tests at any site were significant at the .05 level, so these data will not be discussed further.

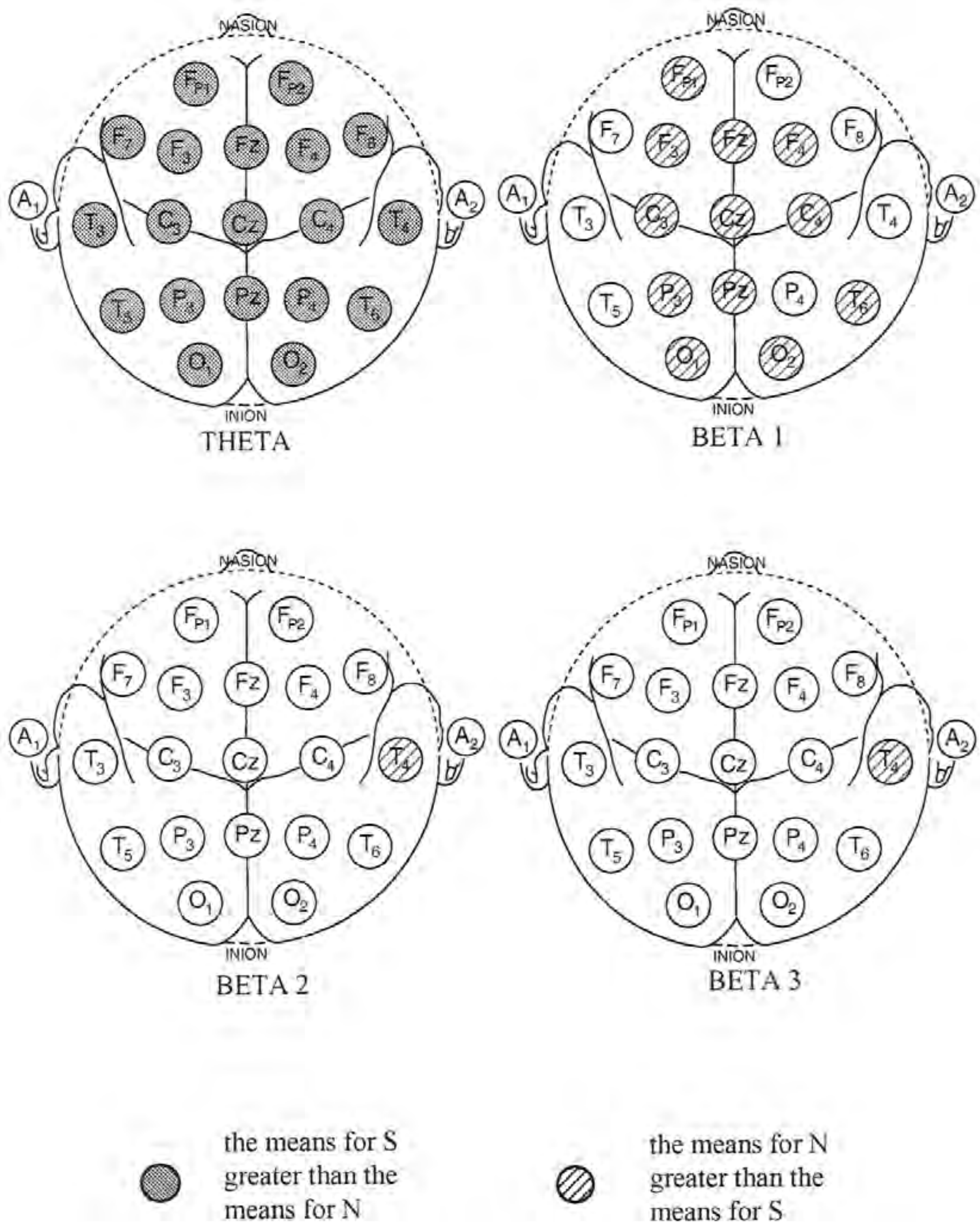
The distribution of significant sites based on the Tukey *post hoc* tests for the Thinking–Feeling dichotomy is found in FIGURE 3 (SEE PAGE 41). Individuals preferring Feeling produced significantly greater mean theta amplitude than did individuals who preferred Thinking, primarily at frontal sites *F*p1, *F*p2, and *F*4. The alpha data, like all the other remaining bandwidths, also showed that Feeling individuals produced greater mean amplitude than Thinking individuals. For the alpha bandwidth data, this held for frontal sites *F*p1, *F*p2, *F*7, *F*3, and *F*4; temporal sites T3, T5, and T6; parietal sites P3, P4, and Pz; and occipital site O2. The beta 1 bandwidth revealed that Feeling types produced greater mean amplitude at frontal sites *F*p1, *F*p2, *F*3, *F*z, *F*4, and *F*8; temporal sites T3, T5, and T6; parietal sites P3, Pz, and P4; and both occipital sites O1 and O2. Significant differences in the beta 2 bandwidth were found at frontal sites *F*p1 and *F*p2, temporal sites T5 and T6, and both occipital sites. Beta 3 data were somewhat similar to the beta 1 data in that Feeling types also produced greater mean beta 3 amplitude than Thinking types at frontal sites *F*p1, *F*p2, and *F*4; temporal sites T5 and T6; parietal sites Pz and P4; and both occipital sites.

Judging–Perceiving Dichotomy. The MANOVAs for the Judging-Perceiving dichotomy yielded significant personality by electrode site interactions for the theta, alpha, beta 1, beta 2, and beta 3 bandwidths: Wilks' $\lambda = .77$, $F(18, 115) = 1.92$, $p < .03$; Wilks' $\lambda = .71$, $F(18, 148) = 3.31$, $p < .0009$; Wilks' $\lambda = .67$, $F(18, 412) = 11.07$, $p < .0009$; Wilks' $\lambda = .65$, $F(18, 148) = 4.51$, $p < .0009$; and Wilks' $\lambda = .73$, $F(18, 278) = 5.85$, $p < .0009$, respectively. No other main effects or interactions were significant. Although the personality type by recording sites were significant for the theta bandwidth, none of the individual *post hoc* tests at any site was significant at the .05 level, so these data will not be discussed further.

FIGURE 4 (SEE PAGE 42) shows the remaining significant sites for the Judging–Perceiving dichotomy. Judging types produced greater mean alpha bandwidth

Figure 2. Sensing–Intuiting

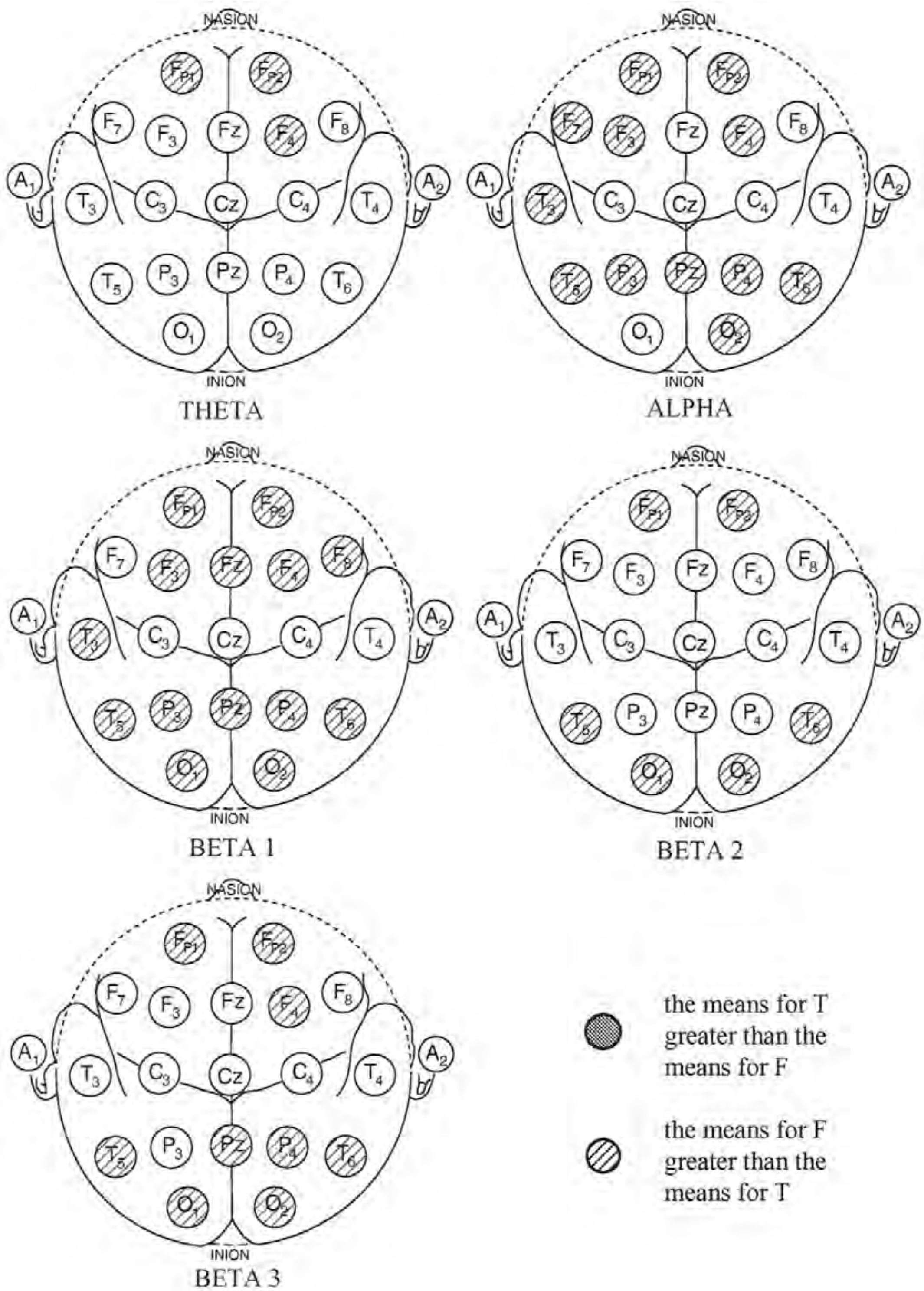
Significant site differences based on a Tukey at .05 for the different bandwidths for the personality dichotomy of Sensing–Intuition (S–N).



Peter C. Gram, Bruce R. Dunn, and Diana Ellis, Relationship Between EEG and Psychological Type.

Figure 3. Thinking–Feeling

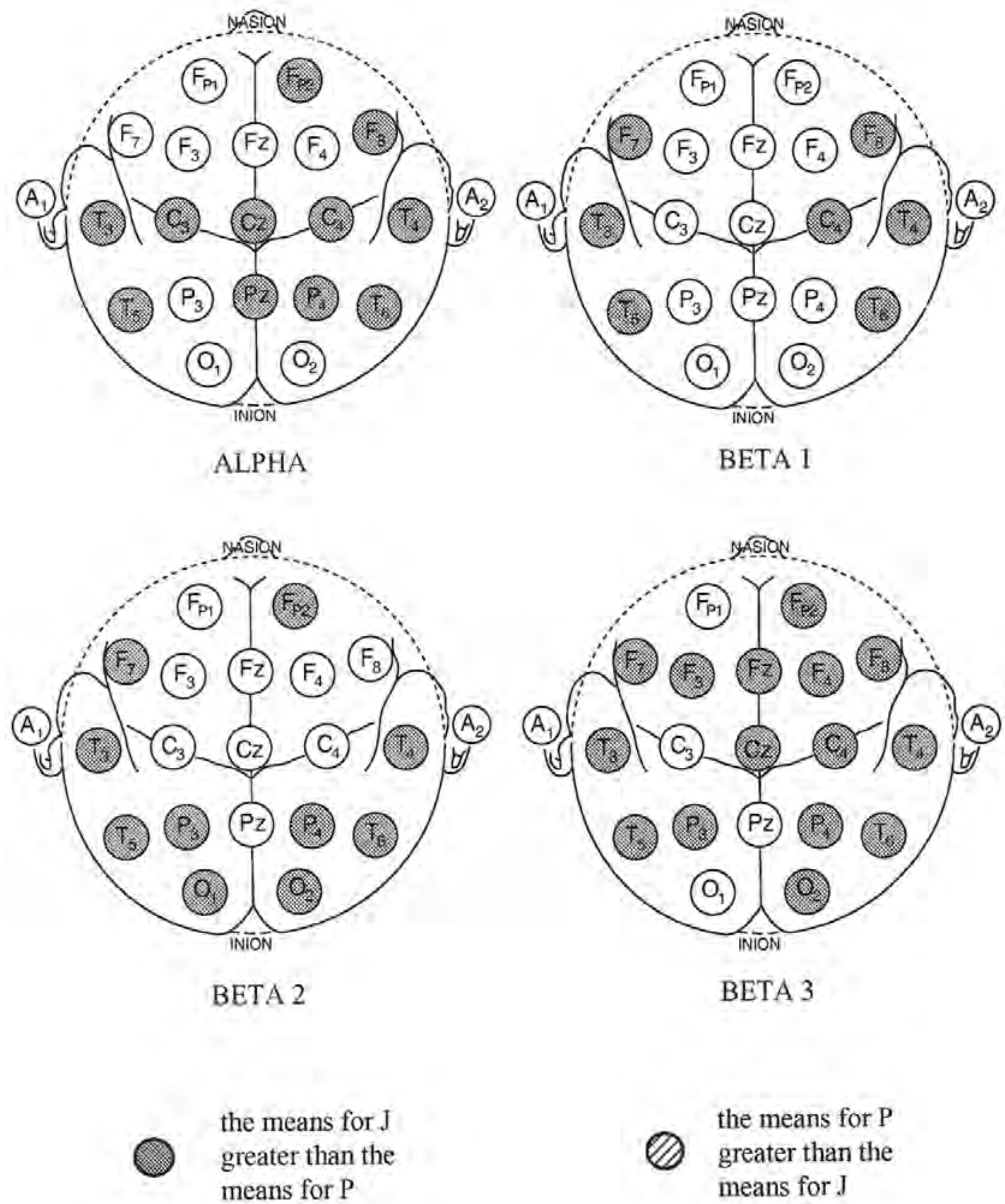
Significant site differences based on a Tukey at .05 for the different bandwidths for the personality dichotomy of Thinking–Feeling (T–F).



Peter C. Gram, Bruce R. Dunn, and Diana Ellis, Relationship Between EEG and Psychological Type.

Figure 4. Judging–Perceiving

Significant site differences based on a Tukey at .05 for the different bandwidths for the personality dichotomy of Judging–Perceiving (J–P).



Peter C. Gram, Bruce R. Dunn, and Diana Ellis, Relationship Between EEG and Psychological Type.

amplitude than did Perceiving types at two frontal sites, *F*p2 and *F*8, all temporal sites, all central sites, and parietal sites Pz and P4.

Js also produced greater mean beta 1 amplitude bilaterally at frontal sites *F*7 and *F*8; temporal sites T3, T4, and T6; as well as the central site C4. A similar pattern occurred in beta 2 data, in which Judging types generated greater mean beta 2 amplitude than Perceiving types at frontal sites *F*p2 and *F*7, all temporal sites, parietal sites P3 and P4, and both occipital sites. With the exception of frontal site Fp1, central site C3, parietal site Pz, and occipital site O1, Judging types produced greater mean beta 3 amplitude than Perceiving types at all sites.

DISCUSSION

Our data strongly support the basic tenets of Eysenck's (1967) biological theory of personality concerning arousal and suggest that, at a minimum, the Extraversion–Introversion scale of the MBTI tool is measuring these constructs at least as well as Eysenck's own EPI index (Eysenck & Eysenck, 1964). Unlike much of the past research, which only examined changes in alpha bandwidth activity (see Gale & Edwards, 1986), we found differences in the beta 2 and beta 3 bandwidths as well. Specifically, we obtained the EEG differences proposed by Eysenck. Extraverts produced greater mean alpha bandwidth amplitude, whereas Introverts produced more amplitude in the higher frequency beta bandwidths.

If past researchers based the discrimination of Extraverts and Introverts on data that primarily included beta 1 activity (e.g., Gale et al., 1969; Gale et al., 1971), it might explain why equivocal results were obtained. Our data show that the beta 1 bandwidth (13–25 Hz) is a mixture of both greater mean amplitude for Introverts at one frontal site and for Extraverts at another. As mentioned above, the beta 2 and beta 3 bandwidth data were more definitive. Introverts generated more activity in the beta 2 and beta 3 bandwidths than Extraverts at all significant recording sites.

It is difficult to compare the differences between Extraverts and Introverts in Gale et al. (1969) and the present study for a number of reasons: First, their data are problematic because they used a bipolar reference in the occipital area only, with the inherent problems associated with this type of reference. Second, the bandwidths they used were not the same as the ones we used; their filters included both high alpha and low beta in one bandwidth (11.5–14.5 Hz), and they used only one other beta bandwidth (14.5–20 Hz). The latter is similar to our beta 1 bandwidth and includes the concomitant problems with using that bandwidth.

In contrast to Rösler (1975), we did not find significant differences between Extraverts and Introverts in either the delta or the theta bandwidths. In Rosler's study, the delta and theta bandwidths just barely reached statistical significance and only occurred in a triple interaction of task, frequency, and Extraversion, and specifically appeared only when the subjects were in a stressful task situation (e.g., calculation under pressure). Their tasks did not correspond to our eyes-open baseline condition, which was not as stress-inducing.

The other purpose of this study was to explore the possibility that each of the other MBTI dichotomies may have unique EEG distribution patterns across cortical recording sites. When participants were divided according to the S–N dichotomy, analysis of the EEG bandwidth data showed that Sensing types displayed significantly more mean amplitude at every cortical site in the theta bandwidth than Intuitive types. No other personality dichotomy showed such strong differences in the theta bandwidth than Intuitive types. No other personality dichotomy showed such strong differences in the theta bandwidth, and in no other bandwidth was the number of significant recording sites as pervasive. Because there was little activity in the relatively sparse experimental room, participants having a preference for Sensing apparently were able to quiet their minds, as indexed by the high levels of theta activity. In the case of the beta 1 bandwidth, this pattern was reversed, so that Intuitive types had greater mean amplitude than Sensing types. This implies that Intuitive types were doing more internal processing than Sensing types in the relatively quiet experimental room.

The data for the Thinking–Feeling dichotomy indicated that Feeling types produced greater mean amplitude in theta through beta 3 bandwidths compared to Thinking types. This pattern was most pronounced for the bandwidths from alpha through beta 3 amplitude data.

Finally, when the Judging–Perceiving dichotomy was considered, Judging types generated greater mean amplitude in the alpha bandwidth through beta 3 bandwidths than Perceiving types. Future research is needed to determine if the Thinking–Feeling and Judging–Perceiving dichotomies' EEG patterns are truly unique.

In conclusion, our data provide additional strong evidence for Eysenck's (1967) basic notions concerning Extraversion and Introversion and suggest that the Extraversion–Introversion scale of the MBTI instrument may be a more reliable measure of this dichotomy than the widely used EPI. Although our study of the remaining MBTI factors was descriptive and exploratory, the results suggest that differential EEG frequency patterns are related to personality variables other than Extraversion–Introversion, particularly to the Sensing–Intuition dichotomy, and therefore further study is warranted.

REFERENCES

Broadhurst A., & Glass, A. (1969). Relationship of personality measures to the alpha rhythm of the electroencephalogram. *British Journal of Psychiatry, 115*, 199–204.

Deakin, J. F. W., & Exley, K. A. (1979). Personality and male-female influences on the EEG alpha rhythm. *Biological Psychology, 8*, 285–290.

DeFrance, J., & Sheer, D. E. (1988). Focused arousal, 40-Hz EEG, and motor programming. In M. Giannitrapani (Ed.), *The EEG of mental activities* (pp. 153–168). Karger: Basel.

Dunn, B. R. (1985). Bimodal processing and memory from text. In V. M. Rentel, S. Corson, & B. R. Dunn (Eds.), *Psychophysiological aspects of reading and learning* (pp. 37–93). New York: Gordon and Breach Science Publishers.

Dunn, B. R., Hartigan, J., & Mikulas, W. (1999). Concentration and mindfulness meditations: Unique forms of consciousness? *Applied Psychophysiological and Biofeedback, 24*, 147–165.

Dunn, B. R., & Reddix, M. (1991). Modal processing style differences in the recall of expository text and poetry. *Learning and Individual Differences, 3*, 265–293.

Eysenck, H. J. (1967) *The biological basis of personality.* Springfield, IL: Charles C. Thomas.

Eysenck, H. J. (1976). *The measurement of personality.* Lancaster, England: Medical & Technical Publishers.

Eysenck, H. J., & Eysenck, S. G. B. (1964). *Manual of the Eysenck Personality Inventory*. London: University of London Press.

Eysenck, H. J., & Rachman, S. (1965). *The causes and cures of neurosis.* London: Routledge & Kegan Paul.

Fenton, G. W., & Scotton, L. (1967). Personality and the alpha rhythm. *British Journal of Psychiatry, 113*, 1283–1289.

Gale, A. (1981). EEG studies of extraversion-introversion: What's the next step? In R. Lynn (Ed.), *Dimensions of personality: Papers in honour of H. J. Eysenck* (pp. 181–208). Oxford: Pergamon.

Gale, A. (1983). Electroencephalographic studies of extraversion-introversion: A case study in the psychophysiology of individual differences. *Personality and Individual Differences, 4*, 371–380.

Gale, A., Coles, M., & Blaydon, J. (1969). Extraversion-introversion and the EEG. *British Journal of Psychology, 60*, 209–223.

Gale, A., Coles, M., Kline, P., & Penfold, V. (1971). Extraversion-introversion, neuroticism and the EEG: Basal and response measures during habituation of the orienting response. *British Journal of Psychology, 62*, 533–548.

Gale, A., & Edwards, J. A. (1986). Individual differences. In M. G. H. Coles, E. Donchin, & S. W. Porges (Eds.), *Psychophysiology, systems, processes and applications* (pp. 431–507). New York: Guilford Press.

Henry, L. E., & Knott, J. R. (1941). A note on the relationship between "personality" and the alpha rhythm of the electroencephalogram. *Journal of Experimental Psychology, 28*, 362–366.

Jaspar, H. H. (1958). The ten-twenty electrode system of the international federation. *Electroencephalography and clinical neuropsychology, 10*, 371–375.

Jaspar, H. H., Solomon, P., & Bradley, C. (1938). Electroencephalographic analogues of behavior problem children. *American Journal of Psychiatry, 95*, 641–658.

Jung, C. G. (1971). Psychological types (H. G. Baynes, Trans., revised by R. F. C. Hull). Volume 6 of *The collected works of C. G. Jung*. Princeton, NJ: Princeton University Press. (Original work published 1921)

Lyons, C. A. (1985). The relationship between prospective teachers' learning preference style and teaching preference style. *Educational and Psychological Research, 5*(4), 275–297.

Montgomery, P. S. (1975). EEG alpha as an index of hysteroid and obsessoid personalities. *Psychological Reports, 86*, 431–436.

Morris, P., & Gale, A. (1974). A correlational study of variables related to imagery. *Perceptual and Motor Skills, 38*, 659–665.

Mundy-Castle, A. C. (1955). The relationship between primary-secondary function and the alpha rhythm of the electroencephalogram. *Journal of the National Institute of Personnel Research, 6*, 95–102.

Myers, I. B., & McCaulley, M. H. (1985). *Manual: A guide to the development and use of the Myers-Briggs Type Indicator.* Palo Alto, CA: Consulting Psychologists Press.

Newman, J. B. (1985). Hemispheric specialization and Jungian typology: Evidence for a relationship. (Doctoral dissertation, Pacific Graduate School of Psychology, 1985). *Dissertation Abstracts International, 46*, 761–762.

Pawlik, K., & Cattell, R. B. (1965). The relationship between certain personality factors and measures of cortical arousal. *Neuropsychologia, 3*, 128–151.

Pfurtscheller, G. (1988). Mapping of event-related desynchronization and type of derivation. *Electroencephalography and Clinical Neurophysiology, 70*, 190–193.

Pollock, V. E., Schneider, L. S., & Lyness, S. A. (1991). Reliability of topographic quantitative EEG amplitude in healthy late-middle-aged and elderly subjects. *Electroencephalography and Clinical Neurophysiology, 79*, 20–26.

Rösler, F. (1975). Die abhangigkeit des electroenzephalogramms von den person lichkeitsdimentionen E und N sensu Eysenck und unterschiedlich aktivierenden situationen (The relationship of electroencephalograms of the personality dimensions E [extraversion] and N [neuroticism] of

Eysenck and different activating situations). *Zeitschrift für Experimentell und Angewandte Psychologie, 12*, 630–667.

Shagass, C., & Kerenyi, A. B. (1958). Neurophysiologic studies of personality. *Journal of Nervous and Mental Disease, 126*, 141–147.

Stenberg, G. (1992). Personality and the EEG: Arousal and emotional arousability. *Personality and Individual Differences, 13*(10), 1097–1113.

Strelau, J., & Terelak, J. (1974). The alpha-index in relation to temperamental traits. *Studia Psychologica, 16*, 40–50.

Ulett, G. A., Glester, G., Winokur, G., & Lawler, A. (1953). The EEG and reaction to photic stimulation as an index of anxiety proneness. *Electroencephalography and Clinical Neurophysiology, 5*, 23–32.

Wilson, M. A., & Languis, M. L. (1989). Differences in brain electrical activity patterns between introverted and extraverted adults. *Journal of Psychological Type, 18*, 14–23.

Wilson, M. A., & Languis, M. L. (1990). A topographic study in the P300 between introverts and extraverts. *Brain Topography, 2*(4), 269–274.

Winter, K., Broadhurst, A., & Glass, A. (1972). Neuroticism, extraversion, and EEG amplitude. *Journal of Experimental Research in Personality, 6*, 444–451.

Peter Gram received his Ph.D. in 1973 from the University of Georgia. He is currently Professor of Psychology at Pensacola Junior College and teaches part time at the University of West Florida. He has been studying the physiological correlates of cognition for the past 20 years.

Bruce Dunn received his Ph.D. in 1973 from Cornell University. He was Professor of Psychology at the University of West Florida, where he was Director of the Laboratory for Studies in Neurocognition and also Associate Director of the Institute for Machine and Human Cognition. He studied the relationship between the brain's EEG patterns and human cognition for more than 25 years before his untimely death.

Diana Ellis received her M.A. in psychology with an emphasis on neurocognition from the University of West Florida in 1988. She subsequently pursued doctoral studies in psychology at Auburn University.

CONTACT

Dr. Peter C. Gram
Department of Behavioral Sciences
Pensacola Junior College
Pensacola, FL 32504
850-484-2545
PGram@pjc.edu