

Comparison of a Parent-Rated *DSM-IV* Measure of Attention-Deficit/Hyperactivity Disorder and Quantitative EEG Parameters in an Outpatient Sample of Children

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Summary: Attention-deficit/hyperactivity disorder (ADHD) was investigated using the parent-as-respondent, 200-item, Coolidge Personality and Neuropsychology Inventory (CPNI) and a quantitative electroencephalograph (QEEG). Parents of 183 children (mean age = 12.2 years) brought to an outpatient private clinic for behavioral and/or emotional problems completed the CPNI including the 18-item *DSM-IV*-based ADHD scale and their children were also evaluated by QEEG. The correlation between the CPNI ADHD scale *T* score and the categorical QEEG parameter (based on the β -theta power ratio) for the identification of ADHD was $r = -0.15$. Using a dichotomous ADHD CPNI measure (positive/negative) and the QEEG β -theta power ratio resulted in an r value of -0.09 . The sensitivity of the QEEG ADHD parameter and the CPNI ADHD scale was 50% and the specificity was 36%. The results stand in contrast to those of Monastra et al. (2001) who found 90% sensitivity and 94% specificity between behavioral measures of ADHD and the QEEG scanning procedure. The lack of correspondence between the two measures is discussed.

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With the recent push for psychologists to implement briefer forms of therapy, an accurate diagnosis of mental and behavioral disorders is perhaps more important now than ever. The quantitative electroencephalograph (QEEG) has received much attention for its potential diagnostic value (e.g., John et al., 1989; Monastra et al., 2001). QEEG is defined as digitized EEG and differs from standard EEG assessment because vast amounts of physiologic brain wave data can be assessed quantitatively. However, claims that the QEEG is highly useful as a diagnostic tool, particularly for the assessment of attention-deficit/hyperactivity disorder (ADHD) and other disorders like dyslexia, remains controversial (e.g., Nuwer, 2003; Yingling et al., 1986).

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Strong evidence for the usefulness of the QEEG in the diagnostic assessment of ADHD comes from a study of 469 participants (aged 6 to 20 years) conducted by Monastra et al. (2001). The investigators analyzed theta wave activity (4–8 Hz) in relation to beta wave activity (13–21 Hz) at the vertex (site Cz). A larger theta-beta power ratio has been shown in the literature to be indicative of ADHD (e.g., Monastra et al., 1999). They found the QEEG to be a reliable measure (test-retest reliability $r = 0.96$), and comparing the QEEG results to behavioral and neuropsychological measures demonstrated that 90% of the behaviorally and neuropsychologically classified ADHD participants were identified correctly by the QEEG procedure, and 94% of a control group were correctly identified as negative for ADHD.

Clarke et al. (2001) have also claimed that during cognitive tasks ADHD children have greater increases in theta activity in frontal and central regions and decreases in beta waves in posterior and temporal regions. More recently, Clarke et al. (2003) found that girls with ADHD had greater relative theta and less relative delta, alpha, and beta than girls without a diagnosis of ADHD. The authors also concluded that there was far less EEG variance in girls with ADHD than in boys with ADHD, and two distinct EEG clusters of girls with ADHD emerged, but both clusters were characterized by increased relative theta. The purpose of the present study was to determine the relationship between a parent-rated, pencil-and-paper evaluation of ADHD symptoms and standard QEEG parameters in a sample of 183 children, brought to an outpatient clinic for behavioral and/or emotional problems. They were evaluated by a clinical psychologist and/or a psychiatrist in an outpatient private practice.

MATERIALS AND METHODS

Participants

One hundred eighty-three children (110 males, 73 females; 151 whites, 7 African Americans, 14 Hispanic Americans, 1 Asian American, and 10 children of other ethnicities; mean age = 12.22, range = 6 to 18 years) were evaluated by a clinical psychologist or psychiatrist for their behavioral and/or emotional problems over a 1-year period at an outpatient private practice. At least some of the parents suspected their children had ADHD. The parents paid for the evaluations, and all gave their informed consent for the subsequent analyses of their children's data.

QEEG

The children's brainwave data were recorded by a standard commercially available QEEG acquisition unit. QEEG data were gathered by technicians/psychological assistants in an outpatient private practice. The assistants were trained by the company that provided the QEEG system. A QEEG report was then generated by the company and provided to the clinicians. The QEEG report includes an overall (positive or negative) ADHD diagnosis (with ADHD subtype if positive), alpha, beta, delta, and theta relative power values bilaterally at frontal, central, parietal, temporal, and occipital sites, and a central site θ -beta power ratio. The QEEG wiring procedures and reporting system have been reported in greater detail elsewhere (e.g., Monastra et al., 2001; Swartwood et al., 2003).

Coolidge Personality and Neuropsychological Inventory

The parents of the children completed the Coolidge Personality and Neuropsychological Inventory (CPNI) (Coolidge et al., 2002a), a standardized *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR*; American Psychiatric Association, 2000) aligned measure of children's and adolescents' (aged 5–17 years) psychological and neuropsychological functioning. The 200-item CPNI scales assessed in the present study were (a) four *DSM-IV-TR* Axis I syndromes (conduct disorder, oppositional defiant disorder, major depressive disorder, and ADHD), and (b) executive function deficits of the frontal lobes. The CPNI uses a four-point Likert scale for each item ranging from (1) *strongly false* to (4) *strongly true*. The CPNI normative sample consists of 780 children, aged 5 to 17 years. The reliability and validity of the CPNI scales has been amply demonstrated in a variety of clinical and nonclinical empirical studies (Coolidge et al., 1994, 1992, 2000a, b, 2001, 2002, 2004). See Coolidge et al., 2002a, for greater detail about the CPNI. The CPNI takes about 30 minutes to complete.

QEEG Testing Procedure and Other Testing Procedures

A 19-channel electrode cap, with adherence to the 10 to 20 International electrode placement system (e.g., Jasper, 1958), was used to collect EEG data. There were 19 electrode sites each measuring a different site on the skull. The child was seated in a straightback chair and EEG recordings were conducted when the child's eyes were closed for 3 minutes and when the child's eyes were open and fixed on an object on the wall for 3 minutes. After data collection, the cap was removed and cleaned. The parents either completed the CPNI before or after the children's visit to the clinic.

RESULTS

CPNI Internal Scale Reliabilities

The internal scale reliabilities for the CPNI in the present sample were: ADHD (18 items), $\alpha = 0.92$; Executive Function Deficits (44 items), $\alpha = 0.93$; Conduct Disorder (14 items), $\alpha = 0.76$; Oppositional Defiant Disorder (8 items), $\alpha = 0.90$; Major Depressive Disorder (7 items), $\alpha = 0.75$.

CPNI ADHD T Scores and Categorical QEEG ADHD Diagnosis

A point-biserial correlation was performed to assess the relationship of CPNI ADHD scale *T* scores for the 183 children and their overall QEEG categorical diagnosis (positive or negative for ADHD). There was a small significant negative correlation between the CPNI and the QEEG, $r(181) = -0.15$, $P < 0.04$. The r^2 was approximately 0.02, which indicated that about 2% of the variance in CPNI ADHD scores can be accounted for by the QEEG diagnosis (and *vice versa*). However, the direction of the correlation was opposite of that expected.

A *t* test was also performed between those positive ($n = 101$) on the QEEG categorical ADHD diagnosis and those negative ($n = 82$) on the CPNI ADHD *T* score. There was a significant difference between the two groups, although those who had a positive QEEG ADHD diagnosis had a significantly lower CPNI ADHD mean *T* score (mean = 61.5, $SD = 13.4$) than those who were negative (mean = 65.8, $SD = 13.7$), $t(181) = -2.101$, $P < 0.04$. The correlation of effect size was small ($r = 0.15$).

CPNI ADHD T Scores and QEEG β -theta Power Ratio

A Pearson product-moment correlation between the CPNI ADHD scale *T* scores and the QEEG θ -beta power ratio scores revealed no relationship between the two variables, $r(181) = 0.00$, $P = 0.97$, and $r^2 = 0.00$.

Categorical CPNI ADHD Diagnosis and Categorical QEEG ADHD Diagnosis

A χ^2 test was performed to assess a categorical CPNI ADHD diagnosis with the QEEG categorical diagnosis (positive or negative). Each of the 18 items on the CPNI ADHD scale was collapsed into (0) for answers 1 or 2 indicating little or no evidence for the criterion in question, or (1) for answers 3 or 4 indicating evidence for the criterion. Next, the number of children meeting six of nine criteria for ADHD inattentive type or hyperactive/impulsive type or meeting 12 of 18 criteria for combined type was calculated. This categorical CPNI diagnosis (positive or negative) was compared with the QEEG categorical analysis. On the CPNI, 117 children met the criterion for ADHD ($n = 70$ inattentive subtype, $n = 6$ hyperactive/impulsive subtype, $n = 41$ combined subtype). According to the QEEG, 101 of the children met the criterion for ADHD (all were identified as inattentive subtype); however, only 59 children were mutually identified as having ADHD, and the χ^2 test was not significant: $\chi^2(1, N = 183) = 2.98$, $P = 0.08$. Using the parent's rating of ADHD as the criterion, the QEEG diagnosis had sensitivity of 50% and a specificity of 36%. (See Table 1 for the 2×2 cross-tabulation design summary.)

Categorical CPNI ADHD Diagnosis and QEEG β -theta Power Ratio

To assess whether children diagnosed with ADHD according to the CPNI ($n = 117$) had greater theta-beta power ratios than those who were not diagnosed with ADHD ($n = 66$), a *t* test was performed on the two groups' means. There

TABLE 1. Cross-Tabulation Table for the Concordance of Categorical CPNI and QEEG ADHD Diagnoses

CPNI ADHD Diagnosis	QEEG ADHD Diagnosis		
	Yes	No	
Yes	59	58	= 107
No	42	24	= 66
Total	101	82	= 183

QEEG sensitivity = 0.50 (59/117).
 QEEG specificity = 0.36 (24/66).
 QEEG accuracy = 0.45 (59 + 24/58 + 42).

was no significant difference between their mean theta-beta power ratios (ADHD group mean = 4.38, *SD* = 2.42, non-ADHD group mean = 4.81, *SD* = 2.47), *t* (181) = 1.148, *P* = 0.25. Although the mean values were not significantly different, the means were opposite from that expected, *i.e.*, the ADHD group had a lower theta-beta ratio than the non-ADHD group.

Categorical CPNI ADHD Diagnosis and QEEG Relative Power Values: Females Only

To test the claim made by Clarke et al. (2003) that females with ADHD demonstrate greater relative theta and less relative alpha, beta, and delta, 64 *t* tests were performed between those positive (*n* = 40) and those negative (*n* = 25) for the females on the ADHD CPNI categorical scale on the QEEG’s bilateral relative power values for alpha, beta, delta, and theta. None of the *t* tests were significant, and all correlation of effect sizes fell below the minimum criterion for small (*i.e.*, *r* = 0.10).

Categorical QEEG ADHD Diagnosis and QEEG Relative Power Values: Males Versus Females

To test the hypothesis that males with ADHD typically have greater relative power values for beta waves in frontal regions than females with ADHD, six *t* tests were conducted between the two genders only for those children diagnosed with ADHD by the QEEG. The male means (*n* = 55) were not significantly different than the female means (*n* = 40) at any of the six frontal sites (FP1, FP2, F3, F4, F7, F8). No correlation of effect size reached the minimum criterion for small.

Categorical QEEG and CPNI ADHD Diagnoses and Comorbidity of Executive Function Deficits, Conduct Disorder, and Oppositional Defiant Disorder.

To test the construct validity of both the QEEG and CPNI categorical ADHD diagnoses, the comorbidity of executive function deficits, conduct disorder, and oppositional defiant disorder were examined as they have been purported to be commonly associated with ADHD (*e.g.*, Kuhne et al., 1997; Pennington and Ozonoff, 1996). On the Executive Function Deficits scale of the CPNI, the mean *T* score (58.9, *SD* = 12.6) for those who were positive (*n* = 101) on the QEEG ADHD diagnosis was not significantly different than the mean *T* score (61.9, *SD* = 12.5) for those who were negative for ADHD (mean = 58.9, *SD* = 13.7), *t* (181) =

1.586, *P* > 0.10. The correlation of effect size just met minimum the requirement for small (*r* = 0.12) but mean values for the two groups were opposite of that expected. There was also no significant difference between these two groups on the CPNI Conduct Disorder scale (positive group *T* score mean = 56.2, *SD* = 15.8; negative group *T* score mean = 56.3, *SD* = 12.4; *t* (181) = 0.031, *P* > 0.97), and the correlation of effect size was less than the minimum for small. There was also no significant difference between the two groups on the CPNI Oppositional Defiant Disorder scale (positive group *T* score mean = 60.3, *SD* = 15.6; negative group *T* score mean = 63.7, *SD* = 15.0; *t* (181) = 1.524, *P* > 0.12.). The correlation of effect size was small (*r* = 0.11), and the mean values were opposite of expected.

For the CPNI ADHD categorical groups, those who were positive for ADHD (*n* = 117) had a significantly higher mean *T* score (66.5, *SD* = 9.9) on the Executive Function Deficits scale than those who were negative (*n* = 66; mean = 49.2, *SD* = 8.7; *t* (181) = 11.850, *P* < 0.0005). The correlation of effect size was large (*r* = 0.66). On the Conduct Disorder scale, those who were positive for ADHD had a significantly higher mean *T* score (mean = 57.9.5, *SD* = 15.1) than those who were negative (mean = 53.5, *SD* = 12.4; *t* (181) = 2.000, *P* < 0.05). The correlation of effect size was small (*r* = 0.15). Finally, on the Oppositional Defiant Disorder scale, those who were positive for ADHD had a significantly higher mean *T* score (64.9, *SD* = 14.7) than those who were negative (mean = 56.3, *SD* = 15.1; *t* (181) = 3.768, *P* < 0.0005). The correlation of effect size was medium (*r* = 0.27).

Misattributions of ADHD by Parents

An analysis was conducted of the CPNI profiles of the children (*n* = 66) whose parents suspected that they had ADHD but subsequently did not endorse enough CPNI ADHD criteria for a diagnosis. Of these children, 19 missed by a single criterion for an ADHD diagnosis. For the remaining 47 children, the majority (60%) was reported by the parents as having mild or severe symptoms for a major depressive disorder. Approximately 42% were reported by their parents as having mild or severe oppositional defiant disorder or conduct disorder symptoms.

DISCUSSION

There was little correspondence between the CPNI parent-rated measure of ADHD and any of the QEEG parameters of ADHD in this study, for both the categorical and dimensional measures of ADHD on the CPNI and the categorical or dimensional measures of the QEEG. Furthermore, whereas the CPNI demonstrated strong internal construct validity, as those deemed positive for ADHD on the CPNI had significantly higher executive function deficits, conduct disorder, and oppositional defiant disorder scores, this evidence was lacking on these same scales for the QEEG ADHD diagnosis. These results stand in contrast to previous work by Monastra et al. (2001).

One possibility for the lack of correspondence of the parent-rated measure of ADHD and the QEEG in the present study could be some kind of parental bias or the invalidity of

parental measures of ADHD. Parental measures of ADHD may not provide a “gold standard” of diagnosis; however, parental measures of ADHD and parental measures of other types of childhood psychopathology have been clearly shown to possess more than adequate reliability and validity in the literature (e.g., Behavior Assessment System for Children, Conners’ Rating Scales, Personality Inventory for Children), and parents also remain an important source of information of their children’s behaviors in diagnostic interviews. It was also noted that the correlation between the categorical ADHD QEEG measure and its θ -beta power ratio was $r = 0.64$; thus, a substantial portion of the variance in categorical QEEG ADHD diagnosis resides in the θ -beta ratio. Perhaps additional QEEG measures, other than the θ -beta ratio, may ultimately prove to be of value in the diagnosis of ADHD. It is also curious that the QEEG computerized reports did not contain any diagnosis other than ADHD inattentive type, whereas the CPNI parental measure yielded hyperactive/impulsive and combined ADHD types.

The present study was limited by single parent ratings of ADHD on the CPNI, as ADHD diagnoses could have been bolstered by the ratings of other informants such as a second parent, caretakers, or teachers. The highly quantitative nature of the QEEG is clearly one of its better features. Its solid stability ($r = 0.96$) over time (1 month), as demonstrated by Monastra et al. (2001), is also an important prerequisite to its ultimate validity. QEEG proponents have encouraged the use of multiple diagnostic criteria for the assessment of ADHD, such as structured clinical interviews, parent interviews and parental measures, behavioral observations, neuropsychological tests, and physiologic measures. The present lack of correspondence between the CPNI ADHD scale and the QEEG measures is certainly worthy of further research. Future studies might also include a control group of children who have been determined not to have ADHD to see whether the parental ratings and QEEG still lack correspondence and to what extent the QEEG parameters diagnose ADHD in normal children.

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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES

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