Effects of borderline personality disorder features and a family history of alcohol or drug dependence on P300 in adolescents

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Abstract

Decrement in P300 amplitude have been associated with familial risk for alcoholism as well as several other psychiatric disorders characterized by disinhibited behavior. The present study examined the P300 in relation to Borderline Personality Disorder (BPD) features in adolescents with a paternal history of alcohol or drug dependence. One hundred and seventy-five males and females, aged 14–20, were assigned to groups based on BPD features (BPD+ vs. BPD−), family history of substance dependence (negative FH−, alcohol FHA, drug FHD) and gender. BPD features were assessed using the Structured Clinical Interview for the DSM-III-R questionnaire. P300 ERPs were recorded while each subject performed the Stroop color-word compatibility test. Repeated measures analyses, which included Conduct Disorder and Depression symptoms as covariates, indicated a significant reduction in P300 amplitude in the BPD+ group. There were no significant effects of FH or gender on P300 amplitude. These results document the presence of neurophysiological abnormalities associated with BPD features in an adolescent sample. This effect appeared to be independent of a family history of alcohol or substance dependence. These findings suggest that BPD symptoms during adolescence are relevant to the examination of the physiological antecedents of those forms of adult psychopathology characterized by behavioral disinhibition, including alcohol and drug dependence.

Keywords: P300; Borderline personality disorder; Adolescent; Impulsive behavior; Alcoholism; Substance-related disorders

1. Introduction

Over the last 20 years, a large research literature has developed implicating the P300 event-related electroencephalographic potential (ERP) as a potential biological marker for alcoholism risk.

Several studies have reported P300 decrements among alcoholic patients and their biological relatives (Begleiter et al., 1984, 1987; Hill et al., 1988; Porjesz and Begleiter, 1990; Berman et al., 1993; Hill and Steinhauer, 1993; Polich et al., 1994; Hill et al., 1995a,b; Porjesz and Begleiter, 1998; Ramsey and Finn, 1997). However, a decrement in P300 amplitude is not unique to these individuals. P300 amplitude reductions are also associated with other psychological, psychiatric
and substance use disorders which overlap with alcoholism, including impulsivity (Branchey et al., 1993; Bauer, 2001; McGue et al., 2001; Iacono et al., 2002), Antisocial Personality Disorder (ASPD; Bauer et al., 1994; O’Connor et al., 1994; Costa et al., 2000), Conduct Disorder (CD; Bauer and Hesselbrock, 1999a,b, 2003), impulsive aggression (Barratt et al., 1997; Mathias and Stanford, 1999; Houston et al., in press), psychopathy (Kiehl et al., 1999), Attention-Deficit Hyperactivity Disorder (Klorman, 1991; Johnstone and Barry, 1996) and depression (Blackwood et al., 1987; Bruder et al., 1995; Houston et al., 2003). Recent studies have suggested that these overlapping disorders may mediate or explain, in part, the effects of a family history of alcoholism on P300 amplitude. For example, Bauer and Hesselbrock (1999a,b) demonstrated the significant impact of underlying behavioral/personality disorders, such as CD and ASPD, on P300 amplitude decrements among subjects with a family history of alcoholism. In addition, longitudinal work by Hill and Shen (2002) demonstrated differential developmental trajectories of P300 amplitude, with the lowest amplitude associated with a combination of both childhood psychopathology and a family history of alcoholism. The literature supports the recent suggestion that visual P300 amplitude might prove useful as a trait marker for a spectrum of disinhibiting psychiatric disorders and behaviors (Iacono et al., 2002).

The goal of the present study was to determine if P300 amplitude decrements could be detected within yet another disorder characterized by disinhibited behavior—Borderline Personality Disorder (BPD). It also examined whether the correlates of this disorder would be neurophysiologically similar to those of a family history of alcoholism. BPD is a severe, persistent pattern of behavior characterized by fluctuating affect, an unstable self-image, volatile interpersonal relationships and marked impulsivity. According to the DSM, BPD is one of four Cluster B personality disorders that are described as dramatic, emotional or erratic. Thus, the BPD diagnosis shares some behavioral or symptom patterns with the other Axis II Cluster B diagnoses, particularly ASPD. In fact, there has been some suggestion that these two diagnoses could reflect different manifestations of similar underlying psychopathology (Coccaro et al., 1989; Zanarini et al., 1989, 1990; Paris, 1997).

The literature on P300 findings in BPD is sparse. The few existing studies are consistent in showing reduced P300 amplitude and prolonged P300 latency in adult BPD patients. These studies have utilized a simple auditory oddball task (Blackwood et al., 1986; Kutcher et al., 1987, 1989; Drake et al., 1991) and have not examined the responsiveness of BPD patients to visual stimuli or to challenging cognitive tasks. It is important to note that the patients in these studies were principally recruited from inpatient treatment programs, which are typically inhabited by severely ill patients with multiple disorders. It is unclear whether co-morbid Axis I pathology was always taken into consideration.

The present study endeavored to complement and extend previous P300 research on BPD in several different ways. In contrast to the aforementioned studies of BPD, which used adult subjects, we examined the P300 in a large sample of adolescents. Although the BPD pattern typically manifests in young adulthood, a substantial body of work has recognized the features and/or precursors of the disorder during childhood and adolescence (Bleiburg, 2000; Paris, 2000). In addition, recent research has demonstrated the continuity of BPD features across adolescence (Crawford et al., 2001). Furthermore, the BPD diagnosis in adolescents may precede a diffuse range of adult psychopathology (Becker et al., 2000). Thus, deficits in neurophysiological processing related to BPD features during adolescence may prove useful for studying the development and treatment of adult psychopathology.

In addition, the adolescent sample used in the present study was recruited from the community rather than an inpatient treatment facility. As a result, the subjects did not possess a severe or acute level of psychopathology. They also lacked the complications of multiple co-occurring disorders, including substance dependence, psychosis or bipolar disorder and had never been medicated for a psychiatric problem.

As noted previously, we also examined the relationship between the P300 waveform and a
family history of alcohol or substance dependence in this sample. Previous work has shown that the family members of BPD patients exhibit a higher than expected rate of alcohol and drug abuse (Widiger and Trull, 1993). Considering the large body of research implicating the P300 as a neurobiological risk marker for alcoholism, the current study adds to the literature by focusing on the potential relationship between BPD features and a family history of alcohol or substance dependence.

Contrary to the earlier P300 studies on BPD that used auditory tasks, we employed a modified version of the Stroop color-word task. The Stroop task elicits the P300 in the visual modality, which may be more appropriate for detecting subtle impairment (Polich et al., 1994). Furthermore, the Stroop task measures response disinhibition and dysregulation, which may be more clinically significant and disabling than a disturbance in attention. Thus, it may be an ideal measure for revealing the cognitive disturbances associated with disinhibited psychopathology, particularly those that place individuals at risk for developing personality disorders and/or substance use problems. The Stroop task has been used extensively as a neuropsychological measure in samples characterized by a lack of behavioral control (Grodzinsky and Diamond, 1992; Chevalier et al., 2000; Fishbein, 2000; Kim et al., 2001). Other ERP investigations using the Stroop task have reported cognitive deficits associated with disinhibited psychopathology including Conduct Disorder (Bauer and Hesselbrock, 1999a) and Attention Deficit Hyperactivity Disorder (Miller et al., 1996).

2. Materials and methods

2.1. Subjects

Subjects in the present study were 175 males (n=79) and females (n=96), aged 14–20 years. They were recruited as part of a larger study of conduct problems and familial risk factors for alcoholism and drug abuse. Most subjects were recruited from the greater Hartford area via advertisements or presentations directed at their parents. The remainder was recruited through presentations before high school classes or guidance counselors, YMCA/YWCA organizations, police athletic leagues or similar venues. In order to recruit a variety of participants, different forms of advertisements and presentations were used, including a general ad for a study regarding health and lifestyle issues, as well as other advertisements specifically directed at risk taking/conduct problems or family history.

A prospective subject or his/her parent(s) were invited to telephone a research assistant for additional information about the study. A total of 567 potential subjects were screened and 338 met inclusion criteria for the original study. The decision to include a subject in the analysis was based on direct interviews with the subject and at least one of the biological parents. Each subject and parent was interviewed individually at the University of Connecticut Health Center. At the beginning of the session, a consent form agreement, approved by the Health Center’s Institutional Review Board, was reviewed and signed by each parent and offspring. Subsequently, the 175 subjects in the present analysis were those who completed both the ERP assessment and the Structured Clinical Interview for the DSM-III-R (SCID-II) Personality Disorders Questionnaire (Spitzer et al., 1987).

During the session, a detailed personal psychiatric history was obtained. The Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA; Bucholz et al., 1994; Hesselbrock et al., 1999) surveyed the major psychiatric disorders defined in DSM-III-R. The SSAGA employs DSM-III-R, Feighner, DSM-IV and ICD-10 criteria to define alcoholism and has been shown to be a highly reliable and valid instrument in evaluating a variety of psychiatric conditions (Bucholz et al., 1994; Hesselbrock et al., 1999). This interview also obtained pertinent demographic and medical history data. Prospective subjects were excluded if they reported a history of head injury (e.g. loss of consciousness greater than 5 min), seizures, life-threatening disease, regular psychoactive medication use, alcohol or other drug dependence (excluding nicotine), schizophrenia or bipolar disorder, neurosurgery, major medical disorders (including diabetes, hypertension, renal disease, lupus, cardiac disorders, etc.), or uncorrected visual or auditory deficits.
The assignment of a subject to the Borderline Personality Disorder positive (BPD +) group (n = 87) was based on the DSM-III-R minimum of five or more BPD criteria as indicated by the Structured Clinical Interview for the DSM-III-R (SCID-II) Personality Disorders Questionnaire (Spitzer et al., 1987). Subjects endorsing less than five BPD criteria constituted the BPD negative (BPD −) group (n = 88).

The family histories of alcohol (FHA) and drug dependence (FHD) for each subject were determined according to the primary clinical diagnosis of the biologic father using the father’s self-reported psychiatric history as obtained via the SSAGA. When the father was unavailable for interview, group classification was based upon the father’s history of alcohol/drug problems as provided by the mother on the Family History Assessment Module (FHAM; Rice et al., 1995). Subjects in the family history negative (FH −) group had no first-degree relatives affected with alcohol or other substance abuse problems. In addition, prospective subjects born to mothers who were abusing alcohol or drugs during pregnancy were excluded to avoid the complicating effects of alcohol or drug exposure during gestation.

All subjects completed the following self-report measures: (1) Michigan Alcoholism Screening Test (MAST; Selzer, 1971); The MAST is a 25 item measure that assesses a respondent’s self-appraisal of control of drinking behavior and alcohol-related personal and interpersonal problems. The respondent is asked to respond ‘yes’ or ‘no’ to each question and a total score is derived. (2) Positive and Negative Affect Schedule (PANAS; Watson et al., 1988); The PANAS consists of 60 self-report items designed to assess a respondent’s levels of positive and negative affect. Respondents are asked to indicate to what extent each item described them in general, using a five-point scale ranging from (1) ‘very slightly or not at all’ to (5) ‘extremely.’ Total Negative and Positive Affect scores are produced, as well as several positive and negative subscales (e.g. Hostility, Sadness, Joviality). (3) Risk Taking Questionnaire (RTQ); The RTQ is an instrument currently in development that consists of 51 items addressing a range of adolescent risk-related behaviors (e.g. Have you ever accepted a drug from someone you didn’t know?; Have you ever raced someone in a car?; Have you ever engaged in unprotected sexual intercourse?). The respondent is asked to answer ‘yes’ or ‘no’ to each question and a total score is derived. (4) Zuckerman’s Sensation Seeking Scale form V (SSS-V; Zuckerman, 1994); The SSS-V consists of 40 forced-choice items, which comprise four subscales (10 items each): Thrill and Adventure Seeking, Experience Seeking, Disinhibition and Boredom Susceptibility. Scores are derived for each subscale and these are summed for a total sensation seeking score as well.

2.2. Procedure

Subjects were seated in a sound-attenuated chamber in a comfortable chair. The chair faced a 14-inch computer monitor used for the presentation of visual stimuli. Subjects performed a discreet trial version of the Stroop test in which the stimuli were the words RED, BLUE or TOWN presented in red or blue typeface on the computer monitor. Thus, there were three categories of stimuli (100 trials per category): incompatible, compatible and unrelated. The stimuli were presented with equal probability at a rate of one stimulus every 2.3 s for 100 ms each. Subjects were asked to indicate the color of the word by pressing one of two response keys within a response deadline of 1000 ms. Before data collection began, subjects were required to practice the task and demonstrate comprehension of task instructions. In addition, tests of sensory function (color vision, visual acuity) were administered to identify factors that would artifactually impair performance on the Stroop Test. Access to caffeinated beverages and nicotine were denied throughout the day of testing.

2.3. EEG recording procedures and analysis

The EEG was recorded from tin electrodes placed at 31 scalp sites (ECI Incorporated, Eaton, OH). A single tin electrode placed on the bridge of the subject’s nose served as the reference. A mid-forehead electrode served as the ground. For the detection of eye blink and eye movement
artifacts, a pair of tin electrodes was placed diagonally above and below the left eye. Interelectrode impedances were kept below 5 K.

The 31 channels of EEG activity and one channel of eye movement activity were appropriately amplified (EEG gain = 20 K, EOG gain = 2 K) and filtered (Bandpass = 0.01–30 Hz) using a Grass Instrument Company Neurodata Acquisition System (Model 12). Along with voltage markers used to indicate the onset of significant experimental events (stimulus and response triggers), the EEG and EOG channels were routed to an A-to-D converter, sampled at a rate of 500 Hz for 100 ms preceding and 900 ms following stimulus onset, and stored for offline analysis. Each sampling epoch was digitally filtered and tested for the presence of A-to-D converter overflow as well as for excessive voltage changes (> 100 mV) in the EEG associated with lead sway or other movement artifacts. A positive test for either condition resulted in the exclusion of all data for that epoch. Eye blinks and other eye movement artifacts were removed from the EEG using the algorithm described by Semlitsch et al. (1986). The processed EEG epochs on correct response trials were then sorted by lead and stimulus type and averaged. P300 was identified as the peak voltage in the averaged ERP waveform between 250 and 900 ms following stimulus onset. Amplitude was expressed in microvolts relative to the average voltage during the 100-ms pre-stimulus period. Latency was expressed in ms relative to stimulus onset.

2.4. Statistical analyses

Demographic and self-report data, with the exception of ethnicity, were analyzed using three-way ANOVAs with BPD, FH and gender groups as between-subject variables. Chi-square analyses were used to examine the ethnicity distribution across the six groups. Behavioral data for the Stroop task (response accuracy and latency) were analyzed using repeated measures ANOVA with trial category type serving as the within-subjects variable and BPD, FH and gender groups serving as between-subjects variables.

For ERP data, PCA was applied to the amplitude and latency values in an attempt to reduce the number of independent analyses performed on interrelated data and the overall probability of Type I error. Thus, the input to the PCAs was the correlation matrices of either P300 amplitude or latency measured at each of the 31 scalp locations (Fig. 1) for each stimulus category (incompatible, compatible and unrelated). The six (amplitude + latency × 3 stimulus categories) PCAs yielded identical results consisting of two orthogonal factors. The electrode sites loading highest on the first factor included 17 sites located adjacent to or posterior to the central sulcus: Cz, CP1, CP2, Pz, P3, PO1, P4, PO2, CP5, T7, CP6, T8, P7, P8, O1 and O2. The second factor included the remaining sites. Most of these were located over the frontal lobes: F3, F4, FC1, FC2, F7, FC5, F8, FC6, FP1, AF1, FP2, AF2, Fz and Cz. These two factors are similar to those examined in previous P300 studies in our laboratory (Bauer and Hesselbrock, 1999a,b).
Table 1
Demographic information [Mean (S.D.)]

<table>
<thead>
<tr>
<th></th>
<th>BPD+ FHD (n=32)</th>
<th>BPD+ FHA (n=31)</th>
<th>BPD+ FH− (n=25)</th>
<th>BPD− FHD (n=22)</th>
<th>BPD− FHA (n=24)</th>
<th>BPD− FH− (n=41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>16.2 (1.4)</td>
<td>16.1 (1.6)</td>
<td>16.3 (1.4)</td>
<td>15.9 (1.3)</td>
<td>16.6 (1.5)</td>
<td>17.2 (1.4)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>9.7 (1.6)</td>
<td>9.6 (1.7)</td>
<td>9.9 (1.4)</td>
<td>9.3 (1.2)</td>
<td>10.3 (1.4)</td>
<td>10.9 (1.5)</td>
</tr>
<tr>
<td>% Caucasian</td>
<td>39.3</td>
<td>74.1</td>
<td>56.0</td>
<td>54.5</td>
<td>83.3</td>
<td>48.8</td>
</tr>
</tbody>
</table>

BPD+ = Borderline personality disorder positive; BPD− = Borderline personality disorder negative; FHD = Family history of drug dependence; FHA = Family history of alcoholism; FH− = Negative family history for alcohol or drug dependence.

Mean P300 amplitudes and latencies from these posterior and anterior scalp regions were analyzed via repeated measures analysis of variance. Within each analysis, BPD, FH and gender groups were entered as between-subjects factors while trial category (incompatible, compatible and unrelated) and scalp region (anterior and posterior) served as within-subjects factors. Given that recent work has demonstrated significant effects of conduct disorder (Bauer and Hesselbrock, 1999a,b, 2001) and depression (Houston et al., 2003) on the P300 in adolescent samples, the total number of lifetime, DSM-III-R conduct disorder and depression symptoms reported on the SSAGA (Table 2) were entered as covariates. In all analyses, the Geisser–Greenhouse formula was applied to protect against violations of the sphericity assumption. Corrected degrees of freedom are reported.

3. Results

3.1. Demographic results

Table 1 summarizes the demographic characteristics of subjects assigned to each group. Analyses of the demographic data did indicate minor but statistically significant group differences in age and education. For age, there was a significant main effect for FH group \(F(2,159) = 3.48, P < 0.05\), with post-hoc tests indicating that subjects with a paternal history of cocaine or opiate dependence (FHD) were slightly younger than those with no paternal history \(P < 0.05\). There were no significant age differences between the BPD and gender groups. An interactive effect of BPD by FH on education \(F(2,159) = 4.40, P < 0.05\) indicated that, within the BPD− group, FHD subjects had completed fewer years of education \(P < 0.01\) than those with no history of alcohol or drug dependence. In addition, male subjects had completed fewer grades than female subjects \(F(1,159) = 5.90, P < 0.05\). In light of these group differences in demographics, correlational analyses were conducted between age, education and P300 amplitude. Neither age \((r = -0.029, P = ns)\) nor education \((r = -0.021, P = ns)\) correlated with P300 amplitude. When categorized as Caucasian vs. Other, ethnicity was unevenly distributed across the six groups \(\chi^2 = 16.10, P = 0.007\). In general, the FHA groups contained more Caucasian subjects than the other two FH groups.

3.2. Self-report measures

Table 2 provides a summary of the self-report findings. Analysis of PANAS scores indicated several significant group differences. For the overall Negative Affect score, there was a significant main effect for BPD group \(F(1,157) = 14.70, P < 0.01\) with BPD+ subjects scoring higher in negative affect than BPD− subjects. For the overall Positive Affect score, a significant BPD×Gender interaction was revealed \(F(1,157) = 4.49, P < 0.05\). Analysis for simple effects yielded lower Positive Affect scores for BPD+ female subjects as compared to BPD− female subjects \(F(1,84) = 9.51, P < 0.01\). This pattern was not demonstrated for male subjects. A significant BPD×FH \(F(2,157) = 4.25, P < 0.05\) interaction was also analyzed further for simple effects. However, with Bonferroni corrections, follow-up analyses for FH were non-significant.

BPD+ subjects scored significantly higher on all negative affect subscales of the PANAS: Fear
Table 2
Self-report information [Mean (S.D.)]

<table>
<thead>
<tr>
<th></th>
<th>BPD +</th>
<th>BPD +</th>
<th>BPD −</th>
<th>BPD −</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Total score</td>
<td>2.6 (4.2)</td>
<td>3.1 (7.1)</td>
<td>2.7 (3.9)</td>
<td>1.9 (4.8)</td>
</tr>
<tr>
<td>Positive and Negative Affect Schedule</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative affect</td>
<td>23.9 (6.0)</td>
<td>23.7 (7.0)</td>
<td>20.2 (6.2)</td>
<td>18.8 (5.6)</td>
</tr>
<tr>
<td>Positive affect</td>
<td>33.1 (6.1)</td>
<td>32.9 (6.7)</td>
<td>34.2 (6.9)</td>
<td>36.5 (6.5)</td>
</tr>
<tr>
<td>Fear</td>
<td>12.9 (4.5)</td>
<td>13.2 (4.9)</td>
<td>11.7 (4.4)</td>
<td>11.0 (4.4)</td>
</tr>
<tr>
<td>Hostility</td>
<td>15.5 (4.7)</td>
<td>14.8 (4.7)</td>
<td>12.6 (3.9)</td>
<td>12.1 (3.6)</td>
</tr>
<tr>
<td>Guilt</td>
<td>13.0 (5.3)</td>
<td>13.4 (5.6)</td>
<td>11.1 (4.5)</td>
<td>9.5 (3.5)</td>
</tr>
<tr>
<td>Sadness</td>
<td>12.5 (4.4)</td>
<td>12.3 (5.1)</td>
<td>10.1 (4.0)</td>
<td>9.3 (3.4)</td>
</tr>
<tr>
<td>Joviality</td>
<td>24.8 (5.8)</td>
<td>26.1 (6.7)</td>
<td>26.5 (6.1)</td>
<td>28.0 (7.1)</td>
</tr>
<tr>
<td>Self-assurance</td>
<td>20.5 (4.4)</td>
<td>19.1 (5.1)</td>
<td>19.8 (4.2)</td>
<td>19.7 (4.1)</td>
</tr>
<tr>
<td>Attentiveness</td>
<td>13.1 (3.1)</td>
<td>12.4 (3.1)</td>
<td>13.5 (3.1)</td>
<td>14.9 (3.0)</td>
</tr>
<tr>
<td>Risk taking Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>25.4 (12.5)</td>
<td>15.0 (9.5)</td>
<td>17.2 (8.8)</td>
<td>9.7 (6.9)</td>
</tr>
<tr>
<td>Sensation Seeking Scales</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disinhibition</td>
<td>5.3 (2.4)</td>
<td>4.5 (2.7)</td>
<td>4.8 (2.5)</td>
<td>4.1 (2.8)</td>
</tr>
<tr>
<td>Boredom susceptibility</td>
<td>4.0 (1.8)</td>
<td>3.5 (2.1)</td>
<td>3.6 (2.2)</td>
<td>3.6 (2.2)</td>
</tr>
<tr>
<td>Thrill and adventure seeking</td>
<td>6.7 (2.4)</td>
<td>5.8 (3.2)</td>
<td>6.0 (2.6)</td>
<td>6.0 (2.9)</td>
</tr>
<tr>
<td>Experience seeking</td>
<td>5.2 (1.9)</td>
<td>5.0 (2.3)</td>
<td>5.0 (2.0)</td>
<td>5.1 (2.1)</td>
</tr>
<tr>
<td>Total</td>
<td>21.2 (5.0)</td>
<td>18.8 (7.1)</td>
<td>19.3 (6.6)</td>
<td>18.8 (7.5)</td>
</tr>
<tr>
<td>SSAGA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Conduct disorder symptoms</td>
<td>3.9 (2.6)</td>
<td>2.0 (1.9)</td>
<td>2.3 (1.9)</td>
<td>0.9 (1.0)</td>
</tr>
<tr>
<td># Depressive symptoms</td>
<td>1.7 (2.1)</td>
<td>2.8 (2.7)</td>
<td>1.4 (2.0)</td>
<td>0.7 (1.4)</td>
</tr>
</tbody>
</table>

BPD+ = Borderline personality disorder positive; BPD− = Borderline personality disorder negative; SSAGA = Semi-structured assessment for the genetics of alcoholism.

*Significant difference between BPD groups.

†Significant difference between BPD groups in female subjects only.

‡Significant difference between male and female subjects.

\[ F(1,157) = 4.37, P < 0.05 \], Hostility \[ F(1,157) = 13.34, P < 0.01 \], Guilt \[ F(1,157) = 14.92, P < 0.01 \] and Sadness \[ F(1,157) = 16.97, P < 0.01 \]. There were no significant FH or gender effects for these subscales. There was a significant BPD×Gender interaction for one of the positive affect subscales: Attentiveness \[ F(1,157) = 16.97, P < 0.01 \]. Further analysis indicated that female subjects with BPD scored lower in attentiveness \[ F(1,84) = 16.98, P < 0.01 \]. There were no significant BPD, FH or Gender differences for the other PANAS subscales.

Analyses of RTQ scores indicated significantly higher scores for the BPD+ group as compared to the BPD− group \[ F(1,146) = 24.08, P < 0.01 \]. In addition, there was a significant gender difference: males scored higher than females \[ F(1,146) = 37.43, P < 0.01 \]. There were no significant group differences in the number of alcohol use problems as indicated by the MAST. No significant group differences were found on the SSS-V.

### 3.3. Performance measures

Analysis of response accuracy (# correct/# possible) revealed a significant main effect for trial category \[ F(2,318) = 52.09, P < 0.01 \]. Follow-up analysis indicated that response accuracy for the incompatible type was lower than that for both the compatible \[ F(1,159) = 63.10, P < 0.01 \] and unrelated categories \[ F(1,159) = 91.34, P < 0.01 \] (Fig. 2). There was also a significant main effect for BPD group \[ F(1,159) = 6.75, P = 0.01 \] indicat-
ing poorer overall response accuracy in the BPD+ subjects. A main effect for FH was also revealed $[F(2,159) = 5.35, P < 0.01]$. Curiously, post-hoc analysis indicated better response accuracy in those subjects with a paternal history of alcoholism compared to those subjects with no family history of alcohol or drug dependence ($P < 0.05$).

For response latency, there was a significant main effect for trial category $[F(2,318) = 55.07, P < 0.01]$. Follow-up comparisons indicated consistent differences in response latency across trial category types. Response latency to compatible trials was faster than that to both incompatible $[F(2,159) = 53.64, P < 0.01]$ and unrelated $[F(2,159) = 127.02, P < 0.01]$ trials, and response latency to incompatible trials was faster than that to the unrelated trials $[F(2,159) = 5.64, P < 0.05]$ (Fig. 2). There was also a significant main effect for gender $[F(1,159) = 6.72, P = 0.01]$: male subjects responded faster than females. There were no significant effects of BPD or FH on response latency.

### 3.4. ERP data

Repeated measures analysis of P300 amplitude indicated a significant main effect for BPD group $[F(1,156) = 5.37, P < 0.05]$. BPD+ subjects exhibited lower P300 amplitudes across all stimuli conditions compared to BPD- subjects (Fig. 4). In addition, there was a significant trial category x scalp region interaction $[F(2,312) = 3.41, P < 0.05]$. Analysis of simple effects indicated significant trial category differences for the anterior
scalloping [\(F(2,312) = 5.82, P < 0.01\)]. Simple comparisons at the anterior scalp region indicated greater P300 amplitude for the compatible trial as compared to both the incompatible [\(F(1,156) = 5.91, P < 0.05\)] and unrelated [\(F(1,156) = 10.91, P < 0.01\)] trials (Figs. 2 and 3). There were no significant effects of FH (mean amplitudes: FH− = 12.1 μV, FHA = 13.1 μV, FHD = 12.9 μV) or gender (mean amplitudes: M = 12.2 μV, F = 13.3 μV) for P300 amplitude.

Because previous work has demonstrated effects of nicotine on P300 amplitude (Anokhin et al., 2000), we also conducted correlational analyses in the respective smokers in the current sample. Forty-seven subjects reported a history of cigarette smoking on the SSAGA. However, the relationship between overall P300 amplitude and the reported number of cigarettes smoked per day (\(r = 0.06, P = 0.68\)) was not significant.

Analysis of P300 latency yielded a significant main effect for trial category [\(F(2,312) = 4.01, P < 0.05\)]. Analysis of simple effects indicated shorter P300 latency in response to compatible trials as compared to the unrelated [\(F(1,156) = 7.06, P < 0.01\)] trials (Fig. 2). There was also a significant main effect for scalp region [\(F(1,156) = 7.47, P < 0.01\)] indicating shorter P300 latency for the posterior region. There were no significant BPD, FH or gender effects for P300 latency.

4. Discussion

The demonstration of reduced P300 amplitude in BPD+ subjects is consistent with previous work suggesting an inverse relationship between disinhibited behavior and P300 amplitude. The P300 decrement associated with BPD is further supported by the behavioral performance finding of poorer response accuracy in the BPD+ group. Interestingly, the P300 reduction in BPD+ subjects appeared to be independent of a family history of alcohol or substance dependence in this sample. Although the absence of a FH effect is contrary to some of the previous P300 studies in individuals at-risk for alcoholism, it is consistent with more recent findings suggesting that externalizing disorders, and particularly Conduct Disorder, mediate the purported relation between FH and P300 (Bauer and Hesselbrock, 1999a,b).

The literature on P300 in adolescent subjects at-risk for alcohol or drug dependence is substantial.
To our knowledge, the present study is the first to examine the P300 differences related to BPD in adolescents. The reduced P300 amplitudes attributed to BPD in the present study suggest that BPD features may influence the same neurophysiological substrates as those, which underlie other Axis II disorders in adolescents.

Another aspect of the study was the examination of group differences in affect, risk-taking, and alcohol problem measures. As might be expected, the BPD+ and BPD− groups differed significantly on a number of the PANAS scales: BPD+ subjects generally scored higher on negative affect variables. Interestingly, the BPD+ subjects also scored higher on the Risk Taking Questionnaire, but not on Zuckerman’s Sensation Seeking Scales. On the surface, risk-taking and sensation-seeking might appear to operationalize the same concept; however, the item content of these scales is quite different. Most of the RTQ questions focus on specific behaviors, including many that might fall into the category of self-damaging impulsive behaviors (e.g. ‘have you ever shoplifted from a store or stolen anything...’). Therefore, it is not surprising that the BPD+ subjects scored high on this measure. The SSS-V, on the other hand, includes only a few items relevant to specific behaviors; many of the items focus on the subject’s preferences or desires rather than actual behaviors (e.g. ‘I often wish I could be a mountain climber’; Jackson and Maraun, 1996). Thus it is likely that these two scales assess disinhibited behavior at different levels of analysis — one focusing on its behavioral referents, the other tapping personality dimensions.

Finally, neither the BPD groups nor the FH groups differed in their reported alcohol-related behaviors as measured via the MAST total score. If the present study had focused on adults, then one would have expected differences among the groups with respect to this measure. However, the subjects studied presently were young and are, therefore limited in their exposure to alcohol and drugs. It should be noted that other studies of this adolescent sample have also not found differences in MAST scores among adolescents with or without a family history of alcoholism (Hesselbrock et al., 1992; Ohannessian and Hesselbrock, 1994).

Detecting the effects of these risk factors on alcohol use and alcohol problems among adolescents may require the involvement of other recruitment sites, including substance abuse treatment or juvenile justice facilities. Our recruitment of subjects from the community, and the exclusion of subjects with substance dependence, mitigates against the detection of group differences in alcohol and drug problems.

A few interactions were detected between BPD and gender on the self-report measures. Interactions between gender and BPD should be expected, because BPD is diagnosed more frequently in females (APA, 2000). For example, in female subjects, BPD+ subjects had significantly lower Positive Affect scores on the PANAS. This effect was not seen in male subjects. Similarly, BPD+ females showed lower Attentiveness scores on the PANAS than BPD− females. In addition, males scored higher on the RTQ than females, which is consistent with previously reported gender differences in adolescent risk-taking behavior (Gullone et al., 2000).

Analysis of the within-group effects of stimulus type revealed the expected findings of inhibition and facilitation. Response inhibition was evidenced by diminished response accuracy for the incompatible stimulus category compared to that for the compatible and unrelated stimulus categories. However, response facilitation was demonstrated by a shorter response latency for the compatible stimulus category compared to the other two categories. The effects of stimulus condition were further supported by the analyses of the ERP data. Larger P300 amplitude was found for compatible stimuli as compared to incompatible and unrelated stimuli. These behavioral and ERP findings are analogous to those reported previously (Pfefferbaum et al., 1986; Renault et al., 1988; Christensen et al., 1996; Bauer and Hesselbrock, 1999b).

Despite evidence of Stroop effects, there were no significant interactions between stimulus category and BPD group. In other words, incompatible stimulus trials, which called for the inhibition of an overlearned response, were no more effective in revealing the neurophysiological and cognitive effects of BPD than were control trials. Similarly, compatible trials, which were designed to facilitate
Fig. 4. ERPs recorded from the $P_1$ electrode for compatible, incompatible and unrelated trials. Bold line is the ERP for the BPD+ group and the dotted line is the BPD− group.
stimulus and response processing, also did not enhance our ability to detect the effects of BPD. Instead, BPD+ subjects exhibited a decrement in processing of all stimulus types. There are at least two potential explanations for the absence of an interaction. First, it is possible that the severity of BPD features in the BPD+ group was not sufficient to reveal a subtle interaction. Secondly, it is also possible that the decrements associated with BPD features may be related to a more generalized dysfunction involving attention or resource allocation rather than a specific problem of deficient response inhibition.

Although the P300 is the major focus of this report, it should be acknowledged that upon inspection of Fig. 4, there appears to be a BPD group difference in the amplitude of the N200 component. As an exploratory measure, this component (defined as the peak negative voltage in the averaged ERP waveform between 150 and 300 ms following stimulus onset) was analyzed using the same approach described for the P300 analyses. However, no significant differences related to group or trial category were revealed for N200 amplitude or latency. Thus, this component, as elicited via the Stroop paradigm in the current study, does not appear to be of significant interest as it relates to BPD or FH.

Although the present study provides robust evidence of P300 decrements associated with BPD symptomology, it is important to recognize one important limitation. Because the study was initially designed with respect to familial risk and conduct problems, the subjects were not recruited specifically for their BPD symptoms and were not grouped according to a clinical diagnosis of BPD. Therefore, unlike earlier P300 studies that examined BPD inpatients, the degree of symptom severity in the present sample was subthreshold. However, this feature of the study might also serve as a potential strength inasmuch as significant differences in cognitive processing were demonstrated in individuals characterized by a mild level of BPD symptoms.

As noted, the current findings are consistent with previous research demonstrating P300 decrements in samples characterized by disinhibited behavior. By employing Conduct Disorder and depressive symptoms as covariates in the present study, we attempted to determine whether a residual P300 decrement specific to BPD features remained. It did. Admittedly, analysis of covariance has limitations. Ongoing work conducted in our laboratory is examining P300 amplitude and topography among adolescents without these complicating co-morbidities. Future studies might also involve a longitudinal examination of P300 decrements in patients with BPD for the purpose of determining their stability and relationship to genetic traits.

Finally, the present findings suggest that early intervention is important. Previous research has suggested that the BPD diagnosis in adolescents may represent a risk factor for a wide variety of forms of adult psychopathology (Becker et al., 2000). Therefore, assessing BPD features in adolescents, and their neurophysiological substrates, may prove to be another useful variable in the search for objective measureable risk factors.

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References


