Executive Function, Iowa Gambling Task Decision Making, and Suicidal Risk in Women with Borderline Personality Disorder

by

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ABSTRACT
Neuropsychological deficits may perpetuate the risk and chronicity of psychiatric disorder. Borderline Personality Disorder, characterized by significant suicide risk, intense affect and behavioural dysregulation, is frequently associated with the executive function (EF) deficits of decision making and inhibitory control. However, the role of inhibitory control on decision making remains poorly understood. This study examined the relationships among working memory, cognitive and motor inhibitory control, and IGT decision-making performance in 41 women with BPD and 41 healthy controls. Associations among EF and suicide risk were also explored. Experimental tasks included the Iowa Gambling Task, Digit Span, Stroop and Stop Tasks, and Raven’s Matrices. Only IGT decision-making deficits distinguished BPD subjects from healthy controls. Weaker yet normal range IQ and EFs in BPD women did not explain their disadvantageous IGT performance. Contrary to expectations, IGT deficits in BPD women did not predict any suicidal risk; however, intact interference control was as sensitive to suicidal risk as was depression. Normal interference control was associated with a reduction in suicide risk. While IGT decision making may be a marker for BPD, Stroop interference control is more
sensitive to suicide risk and may represent a vulnerability for suicide that exists beyond psychiatric diagnosis.
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List of Abbreviations

ACC: Anterior Cingulate Cortex
ADHD: Attention Deficit Hyperactivity Disorder
ANOVA: Analysis of variance
ANCOVA: Analysis of covariance
APA: American Psychiatric Association
BAI: Beck Anxiety Inventory
BDI: Beck Depression Inventory
BPD: Borderline Personality Disorder
CANTAB: Cambridge Automated Neuropsychological Test Assessment Battery
CI: Confidence Interval
DLPFC: Dorsolateral Prefrontal Cortex
DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, 4th edition
EF: Executive Function
IGT: Iowa Gambling Task
IQ: Intelligence Quotient
IPDE: International Personality Disorder Exam
MRI: Magnetic Resonance Imaging
OFC: Orbitofrontal Cortex
PFC: Prefrontal Cortex
PTSD: Post Traumatic Stress Disorder
SCR: Skin Conductance Response
SEM: Standard Error of the Mean
SD: Standard Deviation
SCID: Structured Clinical Interview for DSM-IV Disorders
SMH: Somatic Marker Hypothesis
SSRT: Stop Signal Reaction Time
SPM: Standard Progressive Matrices
TBI: Traumatic Brain Injury
VMPFC: VentroMedial Prefrontal Cortex
WAIS: Weschler Adult Intelligence Scale
WCST: Wisconsin Card Sort Test
Chapter 1: Introduction

Background

Borderline Personality Disorder (BPD) is considered the most lethal of all psychiatric illnesses (APA, 2001) and has been characterized as “a stable state of instability” (Kernberg, 1986) that accounts for high rates of suicide and self-mutilation. Core symptoms of the disorder include marked behavioural impulsivity, emotional instability, chronically disturbed relationships, and an apparent inability to learn from prior experiences. The disorder is three times more prevalent in treatment seeking women than it is in men (Paris et al., 1999); often it develops in childhood or early adolescence, thus robbing many sufferers of their full potential to lead meaningful and productive lives. Sadly one in 10 patients with BPD will commit suicide and 75% will engage in chronic self-injurious behaviour, a well known risk factor for suicide attempts (Oquendo et al., 2003; Soloff et al., 2000). Many with the disorder report chronic feelings of being misunderstood by friends, family members, and health care providers, which understandably leads to less than expected therapeutic outcomes.

While the psychosocial factors, psychodynamic, and personality traits associated with BPD traditionally have been well studied, advances in the biological risks associated with the disorder are gaining greater attention, possibly the result of rapid advances in neuro-imaging technologies and other exciting developments in brain science. In keeping with these trends, a growing interest in the cognitive function of individuals with BPD continues to develop. Nevertheless, a consistent neuropsychological characterization of the disorder remains far from certain, despite initial attempts to explore neuropsychological function in BPD occurring as early as the 1980s. Since then, preliminary trends in this slowly emerging field of research indicate that BPD subjects predominantly demonstrate deficits in the domain of executive functions. In particular, processes of inhibitory control and decision making appear to be most frequently affected (Haaland et al., 2009; Ruocco, 2005; LeGris & van Reekum, 2006). Executive functions (EF) are higher order cognitive control processes that involve the abilities to plan, judge, consider, and weigh options; to make complex decisions; to accurately perceive one’s own abilities; and to reorganize, implement, and control or inhibit other thoughts or behaviours.
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(Pennington & Ossington, 1996). These executive functions rely, in large part, on the integrity of the prefrontal cortex (PFC) and its complex neural interconnections with other brain regions (Stuss & Benson, 1986), such that cognitive deficits in BPD may be associated with dysfunctions of the PFC. The PFC is notably heterogeneous in its control of other cognitive functions, but it is believed to sub-serve diverse abilities, such as working memory, interference from competing stimuli, motor inhibition, and complex decision making.

In general, most NP research has focused on the “cool” executive functions implicated in higher order conscious processing as opposed to the “hot” affective processes localized to the emotional (OFC) brain regions (Happaney et al., 2004). A stronger focus on the “thinking” versus the “feeling” brain may be due to the few available laboratory measures that represent functions in the emotional brain regions. In particular, affective decision making about events involving emotionally significant consequences (i.e., meaningful rewards or losses) have not been examined in BPD previously, despite consistent findings of decisional impairment using other decisional tasks (Bazanis et al., 2002; Kirkpatrick et al., 2007; Dougherty et al., 1999). A greater understanding of the inhibitory and decision-making processes of individuals with BPD could enhance the assessment and treatment of their considerable risk for suicide. As the assessment of suicide risk in BPD remains fraught with ambiguity, the role of cognitive impairment—though largely unknown—may confer additional risk and may ultimately benefit clinical practice. Nevertheless, the role of cognitive/NP function as a risk for the disorder and its consequent suicidal behaviour remains virtually untested.

Although not well characterized, Nigg et al. (2005) proposed that the dysregulation of BPD is suggestive of a disinhibitory disorder. However, inhibitory deficits and other EF deficits have also been attributed to other psychiatric illnesses (Moritz et al., 2001) and, thus, lack specificity. Barkley (1997) contended that conceptually distinct forms of disinhibition are believed to underlie behavioural impulsivity; however, these distinctions remain poorly understood and tested (Nigg et al., 2005). While behavioural impulsivity has been strongly linked to BPD and the suicidal risk that typifies the disorder (Brodsky et al., 1997; Links et al., 1999, Soloff et al., 2000; Yen et al., 2004,), not all studies have replicated these associations (Mann et al., 1999; Yen et al., 2009). These inconsistencies may represent different types of inhibitory control processes that contribute to the behavioural impulsivity of BPD.
To date, both general and focal cognitive impairments have been linked to BPD. To compensate for the variable samples and measures used in the neuropsychological research of BPD, we adopted a qualitative approach that sought to clarify the predominant patterns of deficits that were present across samples. Motor inhibition and interference control deficits were evident in as many as 74-86% of the 29 studies reviewed. Notably, although studies of decision making were few in number, they all consistently reported deficits; however, the degree to which these decisional deficits may have been affected by emotional dysregulation, poor executive inhibition, and other EF deficits remains unclear. In general, the stability of EF deficits has been questioned, but preliminary evidence suggests that EF in BPD is heritable and represents stable characteristics, temperaments, or predispositions (Coolidge et al., 2004). EF deficits were found in younger children with BPD-like symptoms who were not yet formally diagnosed (Coolidge et al., 2000; Paris et al., 1999; Zelkowitz et al., 2001). Such findings contradict the notion that EF dysfunction in BPD is primarily the result of the disorder or its treatment, and they might implicate a biological vulnerability that precedes the diagnosis. Arguably, EF may also be compromised during episodes of temporary stressors or psychopathologies by interfering with the attention and concentration required for optimal task performance.

Neuropsychological research offers opportunities to extend our understanding of the mechanisms that may mediate the clinical manifestations of the disorder. While neuropsychological tasks do not affirm localized brain dysfunction, examining relationships among several related tasks with an established sensitivity for a particular brain region provides evidence of the probable involvement of those structures or their circuitries (Rogers et al., 1999). The Iowa Gambling Task (IGT) (Bechara et al., 1994) is one of the few available tasks that assesses emotional decision making under conditions of uncertainty, and it is believed to reflect real-life decisional conflict. Performance on this task represents a form of emotionally biased decision making considered sensitive and specific to ventromedial PFC dysfunction (Stuss & Levine, 2002). The ventromedial prefrontal cortex (VMPFC) is a region of the PFC responsible for the emotional processing and the weighing of reward/punishment cues as accessed through higher order working memory processes (Damasio, 1994). The VMPFC is situated between the dorsolateral prefrontal cortex (DLPFC) and the lower limbic region; it links factual knowledge with bio-regulatory inhibitory mechanisms that affect behavioural self-control (Stuss & Levine, 2002). Interpretations of IGT performance have been guided by the Somatic Marker Hypothesis.
(SMH) (Damsio et al., 1994), which proposes that emotions play a more prominent role in everyday decisions than do strictly higher order logical thinking processes. However, IGT decision making and the executive functions that may influence IGT performance remain an area of ongoing debate (Fellows & Farah, 2005; Maia & McLennan, 2004). As a result, the SMH has become increasingly scrutinized as the sole source of deficient IGT performance. As individuals with BPD manifest a range of inconsistent EF deficits (LeGris & van Reekum, 2006), the need to clarify the relationships among IGT decision making, representing a form of hot EF, and the roles of working memory, interference control, and motor inhibition, all considered “cool EF” on IGT performance was needed. It was important to determine if decision making was a primary focal deficit of BPD or if decision-making deficits were secondary to other more generalized EF deficits.

My interest in the decisions of patients with BPD was driven by observations of their repetitive patterns of rigid and self-defeating behaviour, which were not easily amenable to therapeutic challenge. Many patients with the disorder did not appear to learn from their mistakes, particularly in the interpersonal domain, or they would admit to making poor decisions but would invariably repeat them. Beyond interpreting this behaviour as classic resistance, low motivation, poor insight, or impulsivity, the question arose of whether this decisional behaviour was the result of unrecognized cognitive deficits that limited new learning, the recall of prior learning, and/or the ability to consider or act on more optimal choices. Research with substance abuse populations revealed that decision-making deficits tended to endure into long-term remission, and as such, they are considered stable (Barry & Petry, 2008). While direct comparisons between substance abuse populations and BPD patients are not fully warranted, particularly for those without substance abuse co-morbidity, these findings suggest the importance of early identification of individuals at risk for decisional deficits. Ongoing research on the decision making of BPD subjects may contribute to a clearer conceptualization of their conflicted interpersonal relationships and life-threatening behaviours, which may eventually result in more targeted treatments for these patients.

**Primary Research Questions**

This thesis addresses two primary research questions presented as two separate manuscripts. Manuscript 1 compares a variety of EF in women with BPD relative to healthy controls and examines the relationships between IGT decision making and working memory,
interference control, and response inhibition. Manuscript 2 describes the associations among these EFs and greater suicide risk in women with BPD. No study was located in which this particular combination of EF was examined among any other population. Importantly, to the best of our knowledge, the effects of these unique executive functions on the prediction of IGT decision making and suicide risk had not been previously examined in any at risk population.

**Roadmap of the Thesis**

Chapter 1 provides an overview of BPD and the relevant background leading to the interest and rationale for the proposed research questions. This chapter identifies the primary study questions addressed in the dissertation. Chapter 2 incorporates relevant background literature on the clinical manifestations and etiology of BPD, and it provides a synthesis of the emerging neuropsychological literature associated with this diagnosis. Specifically, a focus on the EF deficits of BPD and the relationships between EF and IGT decision-making performance in non BPD samples is summarized. Known risk factors for suicide in BPD are also reviewed. This chapter includes the study questions and hypotheses that were tested in this preliminary investigation.

Chapter 3 provides additional details of study methodology, including the study design, sampling frame, description of participants, and the measures selected. This chapter also includes the initial or preliminary data analyses that lead to the primary outcome analyses. Chapter 4 includes the first manuscript entitled, “Executive Function and IGT Decision Making in Women with BPD.” This chapter briefly summarizes the research methods and measures utilized. Chapter 5 depicts the second manuscript entitled, “Executive Functions and Suicidal Risk in Women with BPD.” This manuscript format parallels that of the first manuscript in Chapter 4. Chapter 6 concludes with a summary and discussion of the primary study findings, the study strengths and limitations, and the implications for future research.
Chapter 2: Review of the Literature

This chapter provides an overview of BPD, a description of the theoretical etiological risks for the disorder, and the suicidal behaviour commonly associated with the diagnosis. A review of the neuropsychological literature associated with BPD and other psychiatric samples is presented. The literature review provides theoretical background for the hypotheses to be tested in this thesis.

**Borderline Personality Disorder**

Borderline personality disorder (BPD) has long been characterized as a “stable state of instability” (Kernberg, 1986) with core features of emotional and behavioural dysregulation. These symptoms suggest deficits in executive control processes. To meet DSM-IV diagnostic criteria for the disorder (American Psychiatric Association, 1994), subjects must demonstrate five of the following nine symptoms, which begin in late adolescence or early adulthood and are present in a variety of contexts.

1. frantic efforts to avoid real or imagined abandonment not including suicidal or self-mutilating behaviour;
2. a pattern of unstable and intense interpersonal relationships characterized by alternating between extremes of idealization and devaluation;
3. identity disturbance, markedly and persistently unstable self-image or sense of self;
4. impulsivity in at least two areas that are potentially self-damaging (i.e., spending, sex, substance abuse, reckless driving, binge eating) and not including suicide or self-mutilation;
5. recurrent suicidal behaviour, gestures, or threats, or self-mutilating behaviour;
6. affective instability due to a marked reactivity of mood (i.e., intense episodic dysphoria, irritability, or anxiety usually lasting a few hours and, only rarely, more than a few days);
7. chronic feelings of emptiness;
8. inappropriate, intense anger or difficulty controlling anger (frequent displays of temper, constant anger, recurrent physical fights); and
9. transient, stress-related paranoid ideation or severe dissociative symptoms.
Life Course of Borderline Personality Disorder

Borderline Personality Disorder is now prevalent in 4% of the general population, (Kernberg & Michels, 2009) and represents 10% of all psychiatric outpatients and 20% of all psychiatric inpatients. Sixty percent of all personality disorders are diagnosed with BPD and, of those diagnosed, 80% are female (American Psychiatric Association; 2000). Co-morbidity with other illnesses is high. Up to 83% of BPD patients have experienced a major depression, and as many as 66% also suffer from substance abuse/dependence. These two common co-morbidities are high-risk disorders for suicide in their own right. Lieb et al. (2004) summarized the lifetime prevalence rates of other Axis 1 co-morbid disorders in BPD as follows: post traumatic stress disorder (46-56%), social phobia (23-47%), obsessive compulsive disorder (16-25%), panic disorder (31-48%), dysthymia (12 to 39%), bipolar disorder (10-20%), and eating disorders (29-43%). Not surprisingly, the chronicity and co-morbidity of BPD necessitates considerable health care utilization. For example, over 97% of U.S. patients with BPD were seen, on average, by six therapists; 95% received individual therapy, 72% were hospitalized, 56% participated in group therapy, 42% received family therapy, 37% participated in day treatment, and 24% accessed halfway house programs. No Canadian resource utilization rates are available; however, one questions whether rates may be higher in Canada due to a more accessible, albeit strained, mental health care system.

Despite high health care utilization, recovery from BPD following two-three years of treatment suggests that treatment is marginally effective. Nevertheless, 10-year follow-up studies are beginning to reflect more optimistic trends in remission (Zanarini et al., 2007); however, psychosocial adjustment continues to endure (Gunderson et al., 2011). Residual impairment affecting employment, global satisfaction, social adjustment, and overall level of functioning persists into middle age; many individuals tend to function significantly better by the ages of 35 to 40. The mechanisms for this improvement are unknown (Lieb et al., 2004). Other impulsive co-morbidities, such as antisocial personality disorder and substance abuse, also tend to subside during this same period.

Long-term improvement in BPD varies. A minority of patients will be symptomatic into middle age and others will successfully manage a career, remain happily married, and completely recover. These differences may represent various subgroups within the current classification of BPD that are not yet formally recognized or understood. Evidence suggests that
affective instability, increased length of hospitalization, presence of dysphoria, family history of mental illness, younger age of first treatment, presence of maternal psychopathology, and history of parental abuse are risk factors associated with a poorer prognosis (Lieb et al., 2004). Far less is known concerning the factors associated with improved recovery, but they appear to include higher IQ (McGlashan, 1985) and an absence of narcissistic entitlement or parental divorce (Stone, 1990). Interestingly, 10 year prospective studies suggest that women, more than men with BPD experience more severe and enduring psychosocial impairment despite significant symptom remission (Zanarini et al. 2007., Gunderson et al. 2011).

Etiological Theories of BPD

As with most illnesses, multiple risk factors involving biological, psychological, and social domains and their complex interactions are believed to contribute to a greater likelihood of developing BPD. Early etiological theories primarily focused on the environmental risks, and more recent approaches have explored the biological anomalies of the disorder. However, the convergence of one’s environment with one’s biological predispositions remains well recognized. A brief review of the proposed theories of causation follows.

Socio-Environmental Theories. Initial theories focused on the disturbances in the caregiver-child relationship that affected the quality of human contact in infancy and early childhood. Westen and Gabbard (1999) proposed that nurturing environments enabled children to separate and synthesize the good and bad representations of themselves and others. If the parenting was inconsistent, non-nurturing, or overly self-involved, normal ego synthesis did not develop by interfering with the separation/individuation phase of normal development. When caregivers served as external validators and regulators of a young child’s needs and impulses with stable nurturing, the child developed the ability to internally monitor his/her impulses and ultimately developed a stable sense of self (Winnicott, 1960, 1991). Unstable caregiver-child interactions may further transmit the disorder from one generation to the next through negative role modelling and compromised social learning. Others have proposed that disruptions in caregiver-child attachments may be the result of severe environmental stress, trauma, developmental deficit, and maladaptive coping (Paris et al., 1999). Still others have suggested that individuals with BPD maintain strong attachments to their caregivers (Links & Heslegrave, 2000).
Environmental factors vary considerably among those with BPD and may not necessarily involve physical or sexual abuse, emotional neglect, and parents with impulsive or depressive personalities. A history of sexual abuse, though frequently reported by those with BPD, is not necessary for the diagnosis (Lieb et al., 2004) because others with BPD report normal childhood experiences. Paris (1994) argued that children at risk for BPD might have a particularly strong need for an environment providing consistent expectations and high emotional security, which may be threatened by contemporary social norms. Single parent families or dual working parents may increase the child’s exposure to multiple caregivers and, thus, more variable or inconsistent expectations. To support this argument, prevalence rates of BPD diagnosis in the community have increased from 2% to 4%, as reported recently by Kernberg and Michels (2009).

**Integrated Theories of BPD Etiology.** Contemporary theories integrate known environmental risks with biological vulnerabilities, such as Linehan’s (1993) Biosocial Theory of BPD. Linehan proposed that the physiological irregularities of the disorder synergistically interact with dysfunctional environments, resulting in the core symptom of emotional dysregulation. She argued that invalidating environments prevent individuals with BPD from learning how to regulate their emotions and how to tolerate their emotional distress. Knowing when to trust emotions is also problematic for individuals with BPD who tend to invalidate their emotional experiences and rely on others for correct interpretations. Although less clear, the biological components of Linehan’s theory suggest that disruptions of the limbic system, responsible for emotional regulation and attentional control, may manifest as increased sensitivity and exaggerated emotional response to everyday situations.

The Stress Diathesis Model (Mann, 2003; Paris, 1994) similarly proposes that environmental factors interact with one’s genetic vulnerabilities to contribute to the clinical syndrome of BPD. Diatheses represent the neurobiological markers of frontal lobe functioning that are highly heritable (Coolidge et al., 2004; Friedman et al., 2005) and manifest as the neuropsychological deficits of the disorder. Heritability for affective dysregulation has been estimated at 47% (Mann, 2003). Furthermore, traits of impulsivity and aggression are also highly heritable, as evident in the close relatives of patients, and have been attributed to decreased serotonin activity (Coccaro & Kourvassi, 1997; Coccaro et al., 1989). Genetic vulnerability for BPD is less studied. However, moderate to high heritability for BPD is
implicated with evidence of 35% concordance rates in monozygotic twins and 7% concordance in dizygotic twins (Torgerson et al., 2000).

**Neurobiological Theories of BPD.** A comprehensive summary of the growing neurobiological research in BPD is beyond the scope of this thesis, but it is often challenged by the significant degree of co-morbidity that occurs with BPD. A brief summary of the trends of this line of inquiry are presented below.

Neurobiological correlates of the disorder emerged in the early 1980s through claims of an organic subtype in up to 81% of BPD subjects. Histories of seizures, learning disability, head trauma, and attention deficit disorder were prevalent among many individuals with BPD (Andrulonis et al., 1982; Fossati et al., 2002; van Reekum, 1993). MRI studies have consistently shown a smaller hippocampus and amygdala in people with BPD compared to healthy controls (Driessen et al., 2000; Irle et al., 2005; Schmahl et al., 2003; Tebartz van Elst et al., 2003) often proposed to be the result of earlier developmental or childhood trauma. Tebartz van Elst et al. (2003) also found highly significant volume reductions of the left orbitofrontal cortex—an area responsible for decision making—and reductions in the right anterior cingulate cortex—an area needed for attention and impulse control. Driessen et al. (2000) reported reduced bilateral hippocampal and amygdala volumes in 21 psychosis free women with BPD, in contrast to BPD controls with co-morbid PTSD. BPD patients with PTSD showed no differences in volume reductions compared to BPD patients without PTSD. Driessen et al. (2004) subsequently examined PTSD co-morbidity using fMRI in 12 women with BPD, six of whom suffered a history of trauma. Brain activation was observed in response to both traumatic and aversive memories. OFC activation in both hemispheres and activation of Broca’s area was present in BPD only patients. In contrast, only minor activation of the OFC and no activation of Broca’s area were observed in subjects with both disorders. This work suggests that the brain differences in BPD subjects were not explained entirely by PTSD co-morbidity.

Other researchers have focused on the emotional processing deficits associated with the amygdala and limbic systems as central to the etiology of BPD; however, findings appear to be inconclusive. Using fMRI, Herpertz et al. (2001) observed elevated amygdala and medial PFC activation in six women with BPD, relative to controls, when presented with emotionally aversive and neutral slides. BPD patients experienced exaggerated emotional responses to mild stimuli, suggesting that abnormal prefrontal modulation or control may have lead to excessive
emotional response. Donegan et al. (2003) also observed higher than expected amygdala activity in 15 BPD subjects when presented with neutral, happy, sad, or fearful faces. BPD subjects interpreted neutral faces as unnecessarily negative and threatening. Significant co-morbidity in Donegan’s sample did not affect the findings. Co-morbid PTSD, while insignificant, did suggest that amygdala reactivity was bilateral for BPD patients without PTSD and was restricted to the left hemisphere for subjects with both disorders. These deficits are congruent with the emotional over-reactivity and interpersonal and perceptual difficulties commonly observed in many individuals with BPD.

Nonetheless, not all BPD samples have demonstrated emotional processing deficits. Wagner and Linehan (1999) compared emotional recognition in 21 females with BPD, 21 sexually abused non-BPD controls, and 20 healthy controls. BPD patients accurately perceived others’ emotions, particularly that of fear. No differences were found among the three groups in facial recognition. An absence of emotional processing deficits in some BPD samples led researchers to consider alternative approaches to understand how individuals with BPD may use emotional information instead to guide their behaviour (Rogers & Kirkpatrick, 2005). This latter approach may be relevant to the understanding of emotions on the decision-making processes of individuals with BPD.

Functional MRI studies have also shown that that the orbital frontal cortex and anterior cingulate play important inhibitory roles in the regulation of aggression (Schmahl & Bremner, 2006). Silbersweig et al.’s (2007) findings of reduced ventromedial and anterior cingulate activation in BPD subjects during a motor inhibitory task performed under conditions of negative affect suggested that these regions might provide common ground for understanding the dysregulation of the disorder. Positron emission tomography scans revealed glucose hypometabolism in the prefrontal cortex and in the limbic systems of those with BPD when compared to those without the disorder (De La Fuente et al., 1997; Soloff et al., 2003), suggesting a failure of the “rational or executive” prefrontal cortex to regulate the “impulsive limbic system.” However, Juengling et al. (2003) also reported hypermetabolism in the anterior cingulate and in several frontal cortical structures in addition to hypometabolism in the limbic structures.

In summary, biological research in BPD suggests that the brain areas responsible for the regulation and control of emotion appear to be hypometabolic, and activation of limbic areas,
when it occurs, seems excessive. These irregularities may give rise to a failure of the rational thought needed to control emotion, which may in turn contribute to the affective dysregulation of the disorder. Structural brain alterations are associated with the functional irregularities. Amygdala hypermetabolism and abnormal activation of the PFC may be the result of hyperactive limbic structures. Miller (2007) suggested that structures with reduced volume might demonstrate compensatory hypermetabolic activity. Limbic over-arousal may overwhelm the frontal cortex, eventually reducing its effectiveness, but of course, we don’t know whether these brain differences are a cause or a consequence of the disorder. In particular, co-morbidity of PTSD does not appear to fully explain the neurobiological differences observed in BPD subjects. The evidence for emotional processing deficits remains inconsistent and inconclusive, but study samples have been small and may not be generalizable. The growing evidence of OFC/VMPFC related dysfunction in BPD may implicate irregularities of the serotonin and dopamine brain circuitries.

**Overview of Neuropsychological Function in BPD**

Patients with frontal lobe impairment typically demonstrate personality change and problems with planning, initiating purposeful behaviour, regulating emotional response, and impulse control (Luria, 1966). As many of these symptoms mirror those of BPD, researchers in the early 1980s began to explore the neuropsychological function of BPD that may have reflected underlying neurological dysfunction. The clinical similarities among frontal lobe and BPD patients, the chronicity of the disorder, and poor treatment response amid growing evidence of structural and functional brain irregularities continue to provide compelling arguments for the evaluation of frontal lobe functioning in BPD.

O’Leary et al. (2000) published the first review of NP function in BPD, which was based on four comprehensive studies that included her own study. She reported that simple and logical verbal memory and visuospatial organization deficits were present in adults with BPD. All four studies confirmed deficits in complex visual memory, and two of the four studies also reported lowered IQ. In a more recent review, Monarch et al. (2004) noted a lack of comprehensive NP investigations in BPD, frequently involving a single domain with attentional tests losing favour to EF measures. Based on a review of 14 studies, Monarch suggested that difficulties with impulsivity, response inhibition, decision making, and complex visuospatial memory were
present across BPD samples. Digit Symbol performance, representing attention and rapid information processing, was well below all comparison groups.

To account for the significant variability in cognitive domain classification, the variations in the tasks utilized, and the sampling differences across studies of BPD, we undertook a qualitative review of NP research from 1985 to 2006 to identify the most commonly reported patterns of neuropsychological deficits (LeGris & van Reekum 2006). This review produced evidence of both generalized and focal deficits. Twenty-four of 29 studies (83%) reported impairment in one or more cognitive domains irrespective of current levels of depression. Deficits were associated primarily with the functions localized to the dorsolateral prefrontal and orbitofrontal cortical regions. Most frequently reported were the executive function deficits of decision making, which were reported in all of the, admittedly few, studies; inhibitory control difficulties were reported in 71-86% of the studies. Non-EF deficits included visual and verbal memory impairment and attentional and visuospatial organization, as was reported in 60-67% of the studies examining these processes. Least affected were planning, IQ, and spatial working deficits, as was reported in 50-57% of the studies. Given that ADHD co-morbidity was not systematically controlled in most of the studies in our review and because ADHD is associated with significant NP dysfunction, the specificity of NP deficits for BPD beyond that explained by ADHD, and possibly substance abuse, was questioned. This review found that deficits in the domain of EF were most frequently associated with BPD; however, the presence of non-EF deficits may have also compromised specific EF task performance. It is well recognized that basic cognitive processes, such as attention and memory, are required of higher level cognitive processing.

To compensate for the very small samples of BPD participants in NP research, Ruocco (2005) conducted a meta-analysis of 10 studies that assessed six cognitive domains involving primarily female subjects aged 22 to 33 years. Studies utilizing tests of attention, cognitive flexibility, learning and memory, planning, speeded processing, and visuospatial ability were included in this pooled analysis. In contrast to controls, BPD subjects performed more poorly across all domains, with larger effect sizes for deficits in planning, memory, attention, and information processing. Ruocco concluded that these deficits implicated underlying frontal and possible parietal lobe pathology and suggested that prior NP research in BPD was exceedingly underpowered. The global deficits indicative of this analysis suggest that the clinical symptoms
of BPD are most likely the result of disrupted neural connections between the prefrontal cortex and other regions subserving higher cognition.

Haaland et al. (2009) comprehensively assessed five domains of cognitive functioning in adult outpatients with BPD compared to healthy controls. After controlling for IQ, domain summary scores of working memory, attention, long-term verbal memory, and long-term non-verbal memory scores did not differ between the two groups. EF performance was the only domain that differed indicating a selective deficit in BPD involving interference control, planning and problem solving, cognitive flexibility, and decision making. EF deficits were not explained by co-morbid PTSD, clinical depression, or psychotropic medications.

**Executive Function Deficits and BPD**

Considering the dysregulation of BPD, it is not particularly surprising that executive control deficits have been associated with the disorder. The more relevant question concerns which EFs are critical to the disorder and the suicidal behaviour that typifies the disorder. An answer might eventually lead to important assessment and treatment re-considerations. It is well accepted that executive function deficits interfere with future goal-directed behaviour. Luria (1966) observed that patients with frontal lobe damage could not accurately monitor or evaluate the success or failure of their behaviour, they were unable to use information to change or guide future behaviour, and they appeared unconcerned with their failures. Moreover, these patients were hesitant, indecisive, and indifferent to the loss of this critical self-awareness—all symptoms currently known as executive function deficits. Similar behaviours have been observed in individuals with BPD. Despite the complex mechanisms and neurocircuitsry underlying executive function performance (Alvarez & Emory, 2006), these higher order functions are believed to be associated with the three primary divisions of the prefrontal cortex: (1) the dorsolateral prefrontal cortex; (2) the orbitofrontal cortex, which includes the ventromedial prefrontal cortex; and (3) the anterior cingulate cortex. Executive functions, traditionally localized to the dorsolateral PFC regions, are considered devoid of emotion and, thus, classified as “cool” executive functions. As other EFs are more anatomically proximal to the limbic and amygdala (emotional) regions of the brain, they are often referred to as “hot” executive functions because they integrate aspects of both emotion and cognition (Kerr & Zelazo, 2004). Despite the growth of neuro-imaging evidence that supports the sensitivities of EF to various cortical and
sub-cortical regions, the specificity for these regions remains questionable (Alvarez & Emory, 2006).

Evidence of EF impairment has varied among BPD samples. Swirskey-Sacchetti et al. (1993) examined EF and other cognitive function in 10 females with BPD and 10 healthy controls, using a battery of 24 tests. Performance IQ (WAIS Picture Arrangement), fine motor sequencing, and the incongruent (colour/word) condition of the Stroop were the only tasks that distinguished BPD subjects from healthy controls. No differences existed in full scale IQ or education among the groups, although BPD subjects performed at the low range of normal intelligence. Other tests confirmed normal academic ability, such that the focal impairment in this sample was not accounted for by lower intellect. BPD subjects performed similar to controls on the WCST, Trails A & B, and the Stroop word and colour reading sub-tests, indicating normal set shifting and speeded information processing. However, other researchers, who also utilized comprehensive EF batteries, found little evidence of neuropsychological impairment in their inpatient and outpatient samples. Sprock et al. (2000) reported normal speeded information processing on Trails B, Digit Span and Stroop tasks involving the inhibition of emotional and neutral words, in female BPD subjects with Axis I and II co-morbidities. No problems in visual memory or perception were evident on the Rey Osterreith task in BPD women, relative to clinically depressed and healthy control subjects. In contrast to healthy controls, Kunert et al. (2003) found slower reading speed on the Stroop in his inpatient sample of BPD subjects who were deemed free of Axis I disorder. Despite higher behavioural impulsivity and aggression, BPD subjects performed similar to healthy controls on measures of attention, go/no-go inhibition, visual scanning, working memory, cognitive interference control, planning, problem solving, and verbal learning and memory. Moreover, cognitive performance did not differ among medicated and unmedicated patients.

Our review of neuropsychological studies in BPD using healthy control and clinical comparisons (LeGris & van Reekum, 2006) indicated that decision making, considered a newer type of EF, was consistently impaired in 100% (5/5) of the studies located. As many as 86% (6/7) of the studies reported deficits in attentional and interference control, as assessed by the Stroop Task. Deficits in Go/No-go performance and other measures of motor disinhibition were also present in 5 of 7 (71%) BPD studies. Other executive dysfunctions reported in 67-74% of the BPD studies involved slower information processing (Trails and Digit Symbol) and poor
cognitive flexibility and set shifting (via WCST and the Cambridge Neuropsychological Test Automated Battery of ID/ED performance). Functions least frequently affected were IQ, particularly performance IQ (reported in 50% of the studies) and spatial working memory deficits (reported in 55% of the studies).

**EF Deficits in children with BPD-like symptoms.** Three important developmental studies have demonstrated EF deficits in children aged 7-10 years with borderline-like features. These studies support the notion of a biological vulnerability for the disorder, which appeared to be present well before a diagnosis of BPD was established. Paris et al. (1999) examined children with borderline features at a child psychiatric day treatment centre. These children performed significantly worse on frontal lobe tests and executive functions relative to a group of non-borderline-like children attending the same centre. On the WCST, BPD-like children had difficulty learning from errors, maintaining a conceptual set, and demonstrating cognitive flexibility. These children also demonstrated inconsistent levels of attention, poor attention to task, and slower reaction times than did the psychiatric comparison group. These differences were not attributed to co-morbidity or intellectual functioning. In a follow-up analysis of this sample, Zelkowitz et al. (2001) compared the respective contributions of psychosocial factors, including abuse history and EF impairment, to borderline-like pathology. In children aged 9-10 years, both factors made significant, independent, and equal contributions, collectively explaining 48% of the variance in borderline-like pathology. In a separate study of parents of children (boys and girls with a mean age of 11 years) with borderline features, parents reported that their children had significantly more cognitive symptoms and attention deficit disorder compared to parents of children with features of other personality disorders (Coolidge et al., 2004). Together, these studies suggest that by middle childhood, the cognitive function of children with borderline features may be significantly compromised.

**Challenges of EF research.** Beyond the heterogeneity of BPD and the small sample sizes, EF impairment in BPD may also vary according to the classification and interpretation of the experimental tasks utilized. Lezak (1995) suggested that the interpretations of EF are complicated by the multidimensional nature of these higher order processes, which involve more basic attentional, memory, and visuospatial abilities. Thus, EF performance is often hampered by the problem of EF task impurity. Miyaki et al. (2000) suggested that a general lack of
agreement exists concerning what EF tasks measure because similar measures are often defined and interpreted differently. A lack of definitional clarity of EF frequently results in listings of various sub-processes that, in turn, lead to considerable overlap among EF processes. Some believe that EF constitutes a unitary construct, and others view EF as an assortment of dissociable or independent processes, emphasizing the non-unitary nature of EF (Duncan et al., 1997).

A related problem is the use of the same term to refer to conceptually different functions and, conversely, the use of different terms to refer to the same function. For example, the term inhibition may mean suppressing a prepotent response or alternatively the inhibition of irrelevant information. Similarly, cognitive flexibility may be referred to as a shift of mental set, attention or task switching, all of which refer to the same ability. This lack of conceptual clarity gives rise to other challenges of EF research, such as low reliability of tests. While the reasons for low reliability are complex and not completely clear, Miyaki et al. (2000) suggested that individuals adopt different strategies on different occasions or within the same session when performing EF tasks. As EF is considered strongest when the task is novel, repeated encounters may reduce the task’s ability to target the specific cognitive process, which results in low correlations among novel versus familiar task performance. To the extent that EFs are non-unitary, using a single measure of a construct may provide misleading results. As the construct validity of many EF tasks are not yet well established, the nature of the underlying processes of EF performance are most likely underspecified. Together, this literature suggests that one must account, to the extent possible, for the number of potential and relevant processes believed to be affected during the performance of a particular target EF, such as decision making. Although executive function research is difficult, Miyaki et al. suggested reasons for specifying the nature and roles of EF. EF is central to theories of cognitive psychology, and clinically, many disorders (acquired and developmental) involve some EF impairment. A better understanding of the EFs that are associated with a particular disorder may lead to better treatments and therapy.

Despite the challenges of EF research, preliminary evidence suggests that EF deficits are present in many individuals with BPD; these deficits are not attributed to co-morbid depression, substance abuse, or prescribed medication use. While a pattern of decision making and inhibitory impairment is evident, these impairments exist in other disorders (Moritz et al., 2001), including clinical depression and ADHD. As most BPD studies do not control for co-morbid
ADHD, which is strongly characterized by executive dysfunction, the extent of EF that is primarily associated with BPD awaits confirmation. Determining whether early EF impairment increases the risk for BPD or is the result of the disorder and its treatment requires longitudinal study. More importantly, however, if significant EF and other cognitive impairments exist in some individuals with BPD, regardless of whether the impairment preceded or followed the diagnosis, these impairments warrant greater clinical attention. If executive dysfunction goes unrecognized, some BPD patients’ abilities to benefit from current treatments will be compromised, which may explain the poor rates of treatment response. Evidence suggests the need for earlier screening for cognitive impairment in BPD—even, perhaps, before the diagnosis is formalized. The chronicity of the disorder may represent underlying neurological dysfunction.

**Decision making and BPD.** Cohen et al. (2005) suggested that the ability to make decisions under uncertain conditions is arguably one of the most important functions of the brain. For the purposes of this thesis, decision making is considered a complex EF localized to the orbitofrontal/ventromedial cortical brain regions, and it requires the integration of multiple processes from which a single response is chosen. It is well known that humans do not strictly adhere to models of logical decision making, but they are also influenced by emotional and motivational factors. Quartz (2007) posited that decision making may involve logical analysis in situations of certainty or may take the form of complex cost benefit analysis in situations of uncertainty. The type of decision (i.e., certain or uncertain, high or low risk) may lead to different outcomes involving different cognitive processes. For example, novel or uncertain situations would require additional processing that may include flexibility in planning, anticipating various outcomes, monitoring incoming information relative to the overall goal, and evaluating the reward punishment associations of various options. These processes occur concurrently and often under time constraints. Past experience, personal values, consideration of future outcomes, one’s social environment, and importantly, one’s emotional state also form the basis for a particular decision, thus implicating a degree of individuality in the decision-making process.

Ernst and Paulus (2005) have conceptualized decision making according to three stages of primary cognitive operations: (1) the formation of preferences, (2) the execution of an action, and (3) learning from and experiencing the outcome. Stage 1 (formation of preferences or values) recruits both cognitive and affective brain circuitries that may be influenced by a number
of factors, including the physical features of options; the characteristics of expected outcomes, whether positive or negative; the intensity or magnitude of outcomes; the probability and timing of outcomes; the number of options; and previous experience with options and their outcomes. The second stage (execution of an action) may require the suppression of competing actions, implementing sequences of actions, monitoring sub goals, correcting errors, and planning the timing of actions. This stage engages neural systems that support initiation, monitoring, and completion of actions. During the final stage (learning from and experiencing the outcome), values are also assigned to the outcome experience. While the function of forming preferences is based on expected or anticipated values, the function of Stage 3 is to learn from the actual values of a selected option. Understanding and learning the difference between the expected and actual values is critical to this stage; this may involve a reflection of what might have happened if a different option had been selected. The subsequent experience of surprise, regret, and disappointment would enhance learning and future behaviour. Decisions also vary according to the immediacy or delay of expected rewards. Each of these factors recruits specific neural circuits and their neurochemical systems. Understandably, the complexity of processes that may impede decision making remains uncertain.

Although not well studied, decision-making deficits in BPD have been described as difficulties in enduring or tolerating delay, inadequate planning of future options, a disregard of negative consequences, difficulties in utilizing or learning from feedback, a hypersensitivity to reward, and problems in detecting conflicts involving competing interests. In general, deficits in decision making can also include longer deliberation times, the allocation of disproportionate resources for a decision, or the selection of poorly conceived options based on highly improbable outcomes. A recent review of the published literature produced only five studies of decision making in BPD; however, all of them reported impairment among BPD patients, relative to healthy and clinical control comparison subjects.

Three decision studies in BPD have utilized the Cambridge Gambling Task (Rogers et al., 1999). Bazanis et al. (2002) conducted the largest of these studies, hypothesizing that self-harming behaviour may reflect decisional and planning impairments. In a methodologically rigorous design, they examined 42 self-harming inpatients and outpatients with BPD (primarily female) and 42 controls. They also administered a planning and a visual recognition memory task. BPD subjects were absent of TBI, illicit opiate and alcohol dependence/abuse for two
months; they were not currently depressed nor were they on any psychotropic medications exceeding the equivalence of 300 mg of chlorpromazine. Patients and controls were matched on age, gender, and IQ. Behavioural aggression and impulse control measures were acquired through self-report. The findings revealed that the decision-making impairment of BPD patients required longer deliberation times and more frequent selections involving the least probable outcomes. Despite slower deliberations, BPD patients also made earlier bets on the accuracy of their decisions irrespective of whether the bets were large or small. These choices reflected poorly conceived actions that were expressed prematurely. Planning deficits in BPD subjects were described as requiring more attempts to arrive at the correct solution and longer time to make a first attempt at a solution despite normal pattern recognition and spatial location abilities. Bazanis et al.’s findings did not change when subjects with a history of substance abuse and those currently on psychotropics were eliminated from the analyses. Neither impulsive nor aggressive behaviour correlated with any NP measure. Bazanis et al. suggested that a general aversion to delay during decision making may be an important feature of BPD.

To test the specificity of decision making in BPD as compared to ADHD, Dowson et al. (2004) compared the performance of 19 ADHD adults, 19 BPD adults, and 19 healthy controls on the Cambridge Gambling Task (Rogers et al., 1999) and a spatial working memory task. BPD patients were the only group to perform poorly on the decision task, exhibiting longer deliberation time and more impaired performance relative to the ADHD group. Groups performed similarly on the trials in which subjects chose the most probable outcomes. However, on the spatial working memory task, ADHD subjects performed significantly more poorly than did the BPD patients and the healthy controls, suggesting possible differences in prefrontal function among these two heterogeneous and co-morbid disorders.

Kirkpatrick et al. (2007) also used the Cambridge Gambling Task in 17 male prisoners with BPD and 17 male violent offenders without BPD but with other personality disorders. Subjects selected between two simultaneous gambles, a control gamble that consisted of a 50% chance of winning or losing 10 points (less risk) and an the experimental gamble that offered a 33-66% probability of winning an unspecified numbers of points (more risk). This approach provided information about how individuals with BPD processed different cues when selecting actions associated with probable outcomes. A second version of the decision task was also administered in which one of the two gambles was replaced by an escape option. If selected,
subjects did not choose either gamble but progressed to the next selection with their points unchanged. This version assessed whether individuals could use negative feedback to withhold a response and make a choice to avoid risk and uncertainty. The Cambridge Gamble Task explicitly presented the probabilities of outcomes on the computer monitor, thus lessening the load on working memory. BPD subjects exhibited altered processing of punishment when the probability for gain was high. Compared to subjects with other personality disorders, males with BPD increased their choice of risky options when this choice was avoidable. Risky choices among BPD patients were not explained by co-morbid depression, IQ, breadth of personality disorder, or antipsychotic medications. The strongest discriminators among high and low losses when the probability of winning was high were IQ (which improved discrimination) and affective lability and psychopathy scores (which decreased discrimination). Collectively, these findings suggest patterns of decision making in males with BPD involving an insensitivity to punishment and/or a sensitivity to early reward, which is not accounted for by other co-morbid personality disorders or depression.

The Iowa Gambling Task (IGT) had not been previously examined in any BPD sample at the time of this study. The IGT involves a sensitivity to risk in the form of both risk averse and risk seeking behaviours. The Cambridge Gamble task differs from the IGT in that the probabilities of outcomes are explicit on the former, while participants must deduce the probabilities of outcomes on the IGT. Thus, the IGT increases the ambiguity and the working memory load; however, performance on both tasks has been associated with similar IQ levels (Monterosso et al., 2001).

Haaland and Landro (2007) have tested IGT performance in a mixed gender Norwegian sample of 20 patients with BPD and 15 healthy controls, ranging in age from 18 to 40 years. Patients with BPD made fewer advantageous choices than did healthy comparison subjects. Correlations between net IGT score and IQ, as measured by the WAIS ($r = .44$), and net IGT score and depression, as measured by the Hamilton Depression Rating Scale ($r = -.40$), were significant. Patients with BPD and active substance abuse performed more poorly than did patients with BPD without active substance abuse, suggesting a relationship between net IGT performance, depression, substance abuse, and IQ. Congruent with Bechara’s work with lesioned patients, the IGT deficits of BPD participants were characterized as a myopia of the
future, representing an inability to anticipate the future consequences of their actions, whether positive or negative.

Dougherty et al. (1999) examined differences in aggressive responding to provocation and the ability to endure long delays for reward in a group of 14 hospitalized women with BPD compared to 17 healthy controls. Using an impulsivity task, subjects underwent 100 trials in which they could select a smaller immediate monetary reward or a larger, but progressively more delayed, reward. While short delay selections were similar in patients and controls, BPD patients avoided longer delays of reward across trials and had more impaired attentional and impulsivity scores than did controls.

In summary, these studies suggest that poor decision making in BPD may represent a general tendency to avoid delay, irrespective of the magnitude of future reward or loss; it also may implicate a level of impulsivity or sensitivity to immediate reward. Other deficits may involve a greater affinity for risk, which may be the result of negative effect, inefficient learning, or impaired processing of the reward/punishment outcomes. An inability to inhibit previously rewarded responses may further compromise IGT performance. Spatial working memory was not associated with the Cambridge decision deficits, and verbal working memory, as estimated by the Digit Span, was not associated with IGT performance in the Norwegian BPD sample. These findings implicate the separability of working memory and decision-making processes. IQ and IGT associations found in some studies may highlight the importance of timely learning of the risk/reward cues, which could be compounded by anxiety or greater uncertainty commonly experienced by those with BPD. Despite normal IQ and similar years of education, poorer choices and longer deliberation times were present in BPD subjects relative to controls. Differences in decision-making performance were not explained by co-morbid depression, prior substance abuse, or other co-morbid personality disorders, but outcomes were affected by current substance abuse. Interestingly, behavioural measures of impulsivity were not associated with poor decisional performance.

**The Somatic Marker Hypothesis.** The Iowa Gambling Task (IGT) (Bechara et al., 1994) represents one of the few established instruments of emotion based decision making (Dunn et al., 2006). Damasio’s (1994) Somatic Marker Hypothesis (SMH), which was developed through extensive work with ventromedial lesioned patients, has indirectly facilitated the interpretation of IGT decision making in other psychiatric samples. Essentially, the SMH
suggests that the body’s emotional signals or somatic makers are reactivated from prior experiences to favourably bias decision making at the time of deliberation, rather than as a consequence of the decision (i.e., the disappointment of a loss or the excitement of a win). These emotional signals can be experienced consciously or unconsciously, and they are indexed by stronger somatic activation prior to the selection of a risky or threatening option. Choices previously associated with reward are attended to, while selections associated with negative outcomes are inhibited (Bechara et al 2004). In this way, the number of options and the deliberation time are reduced (Clark & Manes, 2004).

The consistent lack of “anticipatory” somatic activation in ventromedial lesioned patients is proposed to be responsible for their disadvantageous IGT performance in spite of their normal intellect, memory, language, and attention. Numerous healthy individuals and other (non-ventromedial) lesioned patients have generated anticipatory somatic markers and consistently performed advantageously on the IGT. On the other hand, no ventromedial patient has generated any anticipatory somatic markers, nor have they performed advantageously. However, ventromedial patients demonstrated somatic activation following reward and punishment IGT selections indicative of normal conditioning responses. Thus, it is believed that these patients do not process or engage emotion normally during complex decisions. These emotional signalling deficits thus compromise their ability to foresee the future consequences of their choices.

Somatic markers are believed to act on two separate neural systems, both of which generate emotion: an impulsive system, wherein the amygdala autonomically triggers emotional signals of immediate outcome, and a reflective system, in which the ventromedial cortex triggers affective signals of longer term outcome, thus integrating both the thinking and feeling dimensions of future outcomes. Impairments in either or both systems result in poor choices (Bechara et al., 1994; Bechara et al., 2005). The ventromedial prefrontal cortex contains circuitry important to reasoning and decision making in everyday life, and it has important functional connectivity with the amygdala, limbic, and working memory structures. This connectivity is critical for the emotionally cued aspects of reasoning necessary for long-term advantageous choices (Bechara et al., 1994; Tranel & Damasio, 2002b). Although somatic marker activation will not be assessed in this preliminary investigation, the SMH will guide the interpretation of IGT performance.
Inhibitory control and BPD. Impulsivity is a behavioural hallmark of BPD; however, not all impulsive self-report measures correlate with inhibitory task performance (Dougherty et al., 1999; Bazanis et al., 2002; Berlin & Rolls, 2004; Nigg et al., 2005), and they may be affected by the different cognitive mechanisms that govern impulsive behaviour (Dougherty et al., 2004). While impulsivity is a tendency to act quickly without consideration of future consequences, response inhibition requires the ability to suddenly and completely stop a previously rewarded thought or action (Logan, 1994). Inhibitory deficits are believed to underlie impulsive behaviour. In his work with ADHD patients, Barkley (1997) distinguished among three different but interrelated processes believed to constitute response inhibition: (1) inhibition of a strong tendency to respond, (2) stopping an ongoing response once it has been initiated, and (3) control of interference from competing stimuli. Measures that assess only one type of inhibitory control may explain the weak associations among the constructs of impulsivity and disinhibition. Others suggest that this dissonance might be due to the highly structured and time limited nature of laboratory performance versus the unstructured nature of real life. Nevertheless, this data suggests that one cannot assume that impulsive behaviour represents general deficits in inhibitory control.

Deficits in cognitive and motor inhibition have been evident in mixed gender BPD samples. Eighty-six percent of studies report difficulties in Stroop interference control, and 74% of studies report problems with motor inhibition (LeGris & van Reekum, 2006). Other EFs frequently affected in BPD samples were speeded information processing (Trails and Digit Symbol) and poor cognitive flexibility and set shifting (WCST and ID/ED), tasks that some suggest also require processes of inhibitory control. While deficits of decision making and inhibitory control are evident in individuals with BPD, the relationship between different types of inhibitory control and decision making has yet to be examined. This is particularly relevant considering the controversy among researchers on the role of “cool” EFs on “hot” IGT decision making.

Working memory and BPD. Working memory requires the storage and manipulation of information in short-term memory, and it is considered critical for the regulation of behaviour and the ability to plan actions to attain future goals (Baddeley, 1997). Thus, working memory is known to guide future decision making. Poor verbal working memory, as estimated by the Digit Span, has been reported in some BPD samples (O’Leary, 1991; Kurtz & Morey, 1999; Monarch
et al., 2004), but not others (Judd & Ruff, 1993; Sprock et al., 2000; Dinn et al., 2004; Haaland & Landro, 2009). Spatial working memory performance appears to be more intact in BPD (Bazanis et al., 1999; Bergvall et al., 2002; Kunert et al., 2003; Berlin & Rolls, 2004; Dowson et al., 2004; Lenzenweger et al., 2004) relative to other BPD samples demonstrating spatial working memory impairment (Dinn et al., 2004; Irle et al., 2005).

Executive Function and Iowa Gambling Task Performance

IGT performance is ambiguous and complex and may rely on multiple executive functions. These EFs may include abilities to respond flexibly to changing rules, to inhibit a dominant response, to initiate a novel solution to a problem, and to monitor and learn from prior experiences (Dunn et al., 2006). Thus, overall decisional performance does not identify which of these processes may be affected. While some EFs may contribute to IGT performance, they may not fully account for, or even be necessary for, advantageous performance, as proposed by the Somatic Marker Hypothesis (Damasio, 1996). Much of Bechara et al.’s (1994, 1998) extensive work with lesioned and substance dependent samples has revealed a dissociation of “hot” IGT performance from other “cool” executive functions. Bechara et al. (1998) found that impairments in decision making could exist in the absence of working memory deficits; however, they suggest that impaired working memory most likely compromises decision-making ability. Nonetheless, other researchers have demonstrated the importance of EF on IGT performance involving processes of reverse learning (Fellows & Farah, 2005), increased working memory load (Hinson et al., 2002) and inhibitory control (Noel et al., 2007). Levine et al. (2005) also found significant associations between IGT performance and working memory, speeded information processing, and set shifting in patients with Traumatic Brain Injuries. They found domain general (cool EF) effects on IGT performance described as asymmetrically dependent. In other words, impaired EF may contribute to poor decision making, but poor decision making does not contribute to EF impairment.

Working memory and IGT performance. Bechara and Martin (2004) compared IGT performance and working memory in 42 substance dependent individuals and 37 healthy controls. Substance dependent individuals performed worse than controls on the working memory and IGT tasks. However, the controls and substance dependent individuals who were equally impaired on the IGT were very different in their working memory performance.
Controls were at a near ceiling level of working memory performance, whereas the substance dependent subjects performed significantly below the controls, demonstrating a separation between decision making and working memory within the control group. This finding suggests that poor working memory does not fully explain the myopia of the future that characterizes poor IGT performance. This relationship was described as asymmetric because decisional impairment was independent of working memory (i.e., those with excellent working memory can still demonstrate poor IGT performance, whereas those with poor working memory tended to make poorer decisions (Bechara et al, 1998).

**Response inhibition and IGT performance.** Individuals with impaired impulse control resulting from damage to certain areas of the prefrontal cortex are known to exhibit abnormalities in real life decision making; however, weak inhibitory control as a factor in poor IGT performance has not been clearly established. Successful IGT performance requires the inhibition of previously rewarding deck selections and switching to alternative decks when severe punishments begin to develop on the initially rewarding decks. Bechara et al. (1994) acknowledged the role of inhibitory control on IGT performance and maintained that the anticipatory somatic markers are, in fact, the body’s signal to stop. Anticipatory somatic markers serve as the emotional decision maker of whether to suppress, such that emotions interact with mechanisms of response inhibition. Bechara et al. argued that impulsivity and response inhibitory control by themselves do not explain when to inhibit, whereas the activation of anticipatory states provides important emotional signals leading to the deliberation of whether to inhibit or not.

Evidence is limited regarding the relationship of traditional measures of executive inhibitory control and IGT performance. In a large sample of substance dependent individuals, normal controls, and ventromedial patients, Bechara et al. (2001) found no differences among groups on measures of Stroop interference, the Tower of Hanoi representing future planning, or the WCST assessing flexibility and set shifting. WCST and Tower of Hanoi tasks have been suggested to recruit processes of inhibitory control; however, none of these measures appeared to influence IGT performance in any group. Intelligence and memory also did not predict poor IGT performance in substance dependent patients. However, when IQ and memory were in the below normal range, IGT decision making worsened.
IGT performance and cognitive inhibition, as measured by the Hayling Task (Burgess & Shallice, 1996), was assessed in 30 recently detoxified alcoholics and 30 matched healthy controls (Noel et al., 2007). Poor cognitive inhibition predicted 20% of the variance in the late stage IGT performance, representing decisions of risk when greater awareness of the probabilities of punishment became increasingly apparent. Working memory and set shifting abilities did not predict late stage IGT performance in this sample. Goudriaan et al. (2005) also found no association between motor inhibition as assessed by Go/No-go performance and net IGT decision making in recently detoxified alcoholics, pathological gamblers, patients with Tourette’s syndrome, and healthy controls. These preliminary findings suggest that cognitive and motor inhibition may be independent or partially independent of IGT performance in clinical and healthy participants.

IQ and IGT performance. Relationships between IQ and IGT performance also remain controversial. Brand et al. (2006) tested verbal intelligence using the North American Reading Test (Nelson, 1982) and the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1997) and found that IQ did not predict IGT performance in healthy controls or stimulant abusers. Similarly, Bechara (2001) did not find IQ to be significant to IGT performance in stimulant abusers or normal controls. When measured by the verbal Shipley Institute Living Scale, no association was found between IQ and IGT performance in Traumatic Brain Injured individuals (Levine et al., 2005). Toplak et al. (2005) also found no association of IQ and IGT performance in adolescents with ADHD. However, other researchers have reported significant relationships between IQ and IGT performance, which might be consistent with the learning required of advantageous IGT performance. Ernst and Paulus (2003) noted a robust association between IQ and IGT performance in ADHD adults and adolescents, and other researchers have reported positive associations between IQ and IGT performance in BPD adults and other psychiatric samples (Monterosso et al., 2001; Haaland & Llandro, 2007; Kirkpatrick et al., 2007; Barry & Petry, 2008). Negative findings may be the result of setting strict IQ limits on participant eligibility, thus reducing the potential, yet important, differences in premorbid functioning among groups, or alternatively, it might reflect partially dependent relationships between IQ and IGT performance. Disrupted attention and cognitive slowing associated with psychopathology may further compromise IQ and IGT task performance (Bechara & Martin, 2004). Because our work demonstrated that 50% of BPD samples performed at a lower range of
IQ (LeGris & van Reekum, 2006), it will be important to assess the influence of general intellect on IGT decision-making performance in BPD subjects.

To summarize, the influence of IQ, working memory, and inhibitory control on IGT performance does not appear to account for all the variation in IGT decision making in clinical or healthy control populations. Current evidence implicates independent or partially dependent (asymmetric) relationships that are congruent with the assumptions of the SMH. In other words, poor IGT performance can exist in the presence of normal IQ and normal range EF, but lower IQ and impaired EF may worsen IGT decision making. This hypothesis will be tested in this preliminary study of women with BPD.

**Demographic/clinical associations with IGT performance.** Age and education have also been shown to be independent of IGT performance in studies using clinical and healthy control subjects (Bechara et al., 2001; Bechara & Damasio, 2002a; Jollant et al., 2005). Age, gender, and education failed to predict IGT performance in substance dependent individuals, ventromedial lesioned patients, and normal controls (Bechara et al., 2001). Only one study (Evans et al., 2004) found that highly educated healthy controls tended to perform poorly on the IGT. Some have speculated that more highly educated subjects are generally less reliant on emotive, intuitive processes. Gender differences across studies demonstrate that males tend to outperform females on the IGT (Reavis & Overman, 2001; Bechara & Martin, 2004; Bolla et al., 2004), although Han et al. (2011) found that depressed adolescent males performed worse than females on the IGT. In a large sample of 197 healthy individuals, Brand et al. (2006) found no effect of gender or education on IGT performance. However, Reavis & Overman (2001) noted that men selected the IGT advantageous decks 79% of the time by the third block, whereas women chose the advantageous decks only 68% at that time point. They suggested that sex related differences in frontal lobe structures and metabolic resting states may underlie these variations in IGT performance. These gender-related inconsistencies point to the importance of controlling for sex related differences and IGT performance.

Remarkably few studies have examined the role of current depression and anxiety levels on IGT performance. Depression and anxiety, assessed with BDI and BAI screens, correlated poorly with IGT performance in 42 substance dependent individuals (Bechara et al., 2001) and in recently detoxified alcoholics, pathological gamblers, individuals with Tourette’s Syndrome, and healthy controls (Goudriaan et al., 2005). Interestingly, Goudriaan et al. (2005) also found no
relationship between co-morbid adult ADHD and IGT performance. Depression, anxiety, and other clinical symptoms might be inseparable from the clinical diagnosis itself and could explain the lack of independent effects of relevant Axis I or II co-morbidities on IGT performance.

**BPD and Risk for Suicide**

Even when self-harm is excluded, a diagnosis of BPD is strongly associated with suicidal behaviour (Brodsky et al., 1997; Yen et al., 2004), beyond that explained by clinical depression and substance abuse. BPD is an important risk factor for both attempted and completed suicides (Runeson et al., 1989). Personality disorder itself accounts for as many as 28% of completed suicides, a rate higher than depression, schizophrenia, or alcoholism (Soloff et al., 1994). The Collaborative Longitudinal Personality Disorders Study (Gunderson et al., 2000) found that approximately 50% of BPD patients experienced one severe suicide attempt. A history of previous suicide attempts in BPD remains the strongest predictor of completed suicides than for any other diagnosis, and increases the likelihood of future suicide attempts four-fold (Oquendo et al., 2003). Sixty-five percent of suicides in BPD are differentiated by a prior suicide attempt, compared to 33% in patients with clinical depression (Stone et al., 1987). On average, BPD subjects have committed more than three lifetime suicide attempts (Soloff et al., 2000), and therefore, they are at chronic risk for suicide completion.

While not necessarily related to the objective severity of depression, substance abuse, or other psychiatric disorder, suicidal behaviour is frequently correlated with subjective assessments of mood or impulsivity. Thus, a diathesis or biological predisposition involving the traits of impulsivity/aggression and pessimism/hopelessness have been proposed to account for why some patients engage in suicide behaviour and others with the same diagnosis do not (Mann et al., 2009). Therefore, suicide is considered not only a response to a current stressor or psychological state, such as depression, but also a biological vulnerability involving traits associated with low serotonin.

The study of suicide risk in BPD initially focused on the clinical symptoms of the disorder (Brodsky et al., 1997; Soloff et al., 2000; Yen et al., 2004), involving impulsive behaviour as well as the traits of impulsive/aggression, affective instability, and poor problem solving also associated with low serotonin (Linehan et al., 1987; Hawton et al., 2003; Yen et al., 2004). Brodsky et al. (1997) examined BPD criteria, childhood trauma, and suicide attempt in 214 inpatients with BPD. Of all the diagnostic criteria, impulsive behaviour—representing two
areas of binge eating, shopping, gambling, substance abuse, or reckless driving—was the only predictor of suicide attempt after controlling for lifetime depression and substance abuse. BPD severity was not associated with any suicidal behaviour, although a history of childhood physical and sexual abuse was associated with lifetime suicide attempts. Researchers also compared impulsive behaviour and impulsive/aggressive personality traits among diagnostic groups in search of a more unifying hypothesis of suicide risk. These approaches produced mixed findings regarding the role of co-morbid affective disorder and substance abuse adding to the risk for suicide in BPD. Many studies suggest that a diagnosis of clinical depression and substance abuse is insufficient to fully explain or predict suicidal behaviour in BPD and other at-risk groups (Soloff et al., 1994; Malone et al., 1995; Jollant et al., 2005; Keilp et al., 2008), indicating the importance of a diathesis or biological vulnerability that may be independent of psychiatric illness. Historical comparisons of suicide attempters versus suicide completers, on the basis of gender and other impulsive-aggressive characteristics, continue to favour trait versus state risks for suicide (McGirr et al., 2007).

Other BPD researchers have studied suicidal risk based on the degree of intentionality and lethality of the suicide attempt. Contrary to common belief, Soloff et al. (2000) confirmed the lethality of suicide attempts in BPD, which mirrored that of clinically depressed patients. Nonetheless, they noted that the presence of both BPD and depression led to more objective planning and greater lethality. Other researchers have proposed that, while substance abuse and depression and other Axis II co-morbidities may increase the risks for suicide completion, these co-morbidities are less predictive of suicide attempts in BPD mediated in part by gender and other personality disorder (Stone, 1994; McGirr et al., 2007; Yen et al., 2009). Attempters are believed to differ from completers, but these distinctions are limited by the low rates of suicide completion and the few psychological autopsy studies examining the precursors to suicide completion. Substantial research suggests that males are at greater risk for completing suicide than are females who tend to engage in more frequent suicide attempts (McGirr et al., 2007). As individuals with BPD manifest repetitive parasuicidal behaviour, involving little or no intent to die, engage in multiple suicide attempts with more serious intent, or ultimately complete suicide, the clinical distinctions of suicidal risk are indeed challenging for clinicians. Unstable interpersonal relations, another core feature of BPD, combined with traits of high rejection sensitivity, fear of abandonment, and intolerance of aloneness are characteristics that commonly
motivate suicidal behaviour in BPD (Yen et al., 2005). Childhood physical and sexual abuse is also a known risk factor for suicide in some, but not all, individuals with BPD.

Irrespective of the trait versus state arguments for suicide risk in BPD, it is increasingly evident that a history of previous attempts remains the strongest predictor of future suicide attempts (Paris et al., 1989; Soloff et al., 2000, 2003; Soloff & Fabio, 2008). However, state/trait interactions appear to increase the risk for suicide. Whether NP deficits in BPD constitute an additional trait like risk factor for suicide attempt is unknown and will be explored in this preliminary investigation.

The following longitudinal studies have attempted to clarify the contributions of state versus trait risk factors for suicide in BPD. A 15-year prospective study indicated that suicide completion was five times greater when individuals with BPD suffered from co-morbid depression (McGlashan, 1986). In another 15-year longitudinal study, Paris et al. (1989) found no difference in the prevalence of affective disorder among 14 BPD patients who committed suicide compared to 100 BPD controls. Paris et al.’s findings were supported by Soloff et al. (1994), who examined the precursors to suicide attempt in 84 BPD patients with and without suicide attempt. Self-reported depressed mood (BDI) and antisocial personality disorder were more predictive of suicide attempt than were objectively assessed clinical depression, alcoholism, or drug abuse. Importantly, the most recent suicide attempt was predicted by the number of prior lifetime attempts. Serious intent was best predicted by the number of attempts and subjective ratings of depression. Soloff et al. (2000) also compared the characteristics of suicide attempters in 81 patients with BPD, 77 patients with major depression, and 49 patients with both disorders. No significant differences in mood, hopelessness, impulsive aggression, number or lethality of previous attempts, medical damage, and objective planning were found among BPD patients and depressed controls. However, patients with both disorders had more frequent suicide attempts and higher levels of objective planning. Traits of impulsive/aggression, hopelessness/pessimism, or BPD diagnosis independently predicted the number of lifetime suicide attempts. In contrast to Brodsky et al. (1997), Soloff et al.’s findings support the role of co-morbid clinical depression in increasing the number and severity of suicide attempts in BPD patients. However, the traits of hopelessness and impulsive aggression, as independent predictors of suicide attempts (beyond diagnosis) in BPD and in clinically depressed patients, implicate the importance of both state and trait risk factors for suicide.
Soloff and Fabio (2008) continued to explore the role of depression and suicide attempts in BPD patients by prospectively following 137 BPD outpatients at one-, two-, and five-year follow-up intervals. At one year, the suicide attempt rate was 19%, which was explained primarily by co-morbid depression and poor social adjustment. At the two-year follow-up, 25% of BPD patients had attempted suicide. While outpatient treatment decreased the short-term risk of suicide attempts, the risks for suicide attempt were increased by hospitalization prior to attempt and poor social adjustment. Among the remaining 122 subjects followed at five years, increased risk was due to hospitalization and medication visits prior to any attempt, a suicide attempt within the first year of follow-up, and low global functioning at baseline. The researchers argued that more attention to social adjustment was needed to reduce both the short- and the long-term risk of suicide attempts in BPD. While clinical depression accrues greater short-term risk, social adjustment difficulties are implicated in the chronic risk for suicide in BPD. Chronic difficulties in the social adjustment of individuals with BPD may implicate neuropsychological dysfunction that represents a cognitive vulnerability or diathesis for suicide.

Yen et al. (2004) also prospectively assessed 621 BPD participants from the Collaborative Longitudinal Personality Disorder Study over a two-year period. Their team of researchers examined each DSM-IV criterion for BPD and their associations with suicidal behaviour, involving parasuicide (no intent to die) and suicide attempts (some intent to die), while controlling for clinical depression, substance abuse, and childhood sexual abuse. In order of importance, affective instability, identity disturbance, and impulsivity most strongly predicted any suicide related act regardless of intent. Depression, substance abuse, and childhood sexual abuse were eliminated as predictors. However, affective instability and childhood sexual abuse did predict suicide attempts with greater intent to die. Yen et al. argued that affective instability may hold greater promise for an understanding of suicide risk in BPD, whereas impulsivity may be more relevant to the repetitive self-harm or parasuicide behaviour, which provides temporary short-term relief from intense psychological pain. These findings support the need to examine the emotional aspects of decision making and suicidal risk behaviour in BPD.

In a later study, Yen et al. (2009) examined negative affectivity, disinhibition, and other facets of behavioural impulsivity as predictors of suicide attempts in 701 subjects with personality disorder. Negative affectivity was defined as neuroticism, negative temperament, and negative emotionality. At a seven-year follow-up, 18% of the participants had attempted
suicide, including six individuals who completed suicide, and 58% of the suicide attempters reported multiple attempts. Seventy-four percent of the suicide attempters met criteria for BPD, compared to 26% who reported no suicide attempts. While more women than men attempted suicide, no differences in age, education, ethnicity, marital, or employment status distinguished attempters from non-attempters. Potential multivariate predictors of suicide attempts included gender, childhood sexual abuse, time course of clinical disorders, disinhibition, impulsivity, and negative affectivity, but only negative affectivity and the lack of pre-meditation significantly predicted suicide attempts. Interestingly, all measures of disinhibition and impulsivity were deleted as predictors of suicide attempts in this study.

Collectively, these studies implicate the importance of targeting the stable risks for suicide attempts involving impulsive/aggressive traits, affective instability, pessimism, poor social adjustment, and current self-reported depression, which increases suicide attempts in BPD. Psychosocial deficits and poor social adjustment appear to perpetuate the long-term risk of suicide in BPD. Clinical depression or dysthymia may interact with more stable traits to increase the acute risk of suicidal behaviour in individuals with BPD. However, the frequency of suicide attempts remains the strongest predictor of future attempts, irrespective of BPD severity, substance abuse, and clinical depression. Self-rated depression is a stronger predictor of suicide attempts in BPD than is clinical depression, and this may reflect the chronic dysthymia that is common to the disorder. It may be impossible to separate a chronic dysthymic state from the diagnosis of BPD, thus minimizing the independent effects of depression on suicide risk. The role of cognitive impairment as a stable risk factor for suicide in BPD has yet to be examined and will be tested in this preliminary analysis.

**IGT Decision Making and Suicide Attempt.** Very few studies have examined IGT decision making and suicide behaviour. Jollant et al. (2005) compared IGT performance in formerly depressed violent and non-violent suicide attempters, compared to formerly depressed subjects with no suicide history and normal controls. All of Jollant et al.’s subjects were free of current Axis I disorder at testing. Violent and non-violent suicide attempters performed significantly more poorly on the IGT than did healthy controls; however, no IGT performance differences were found among the depressed non-suicidal and healthy control groups. Similar IGT performance among the two groups of attempters and the two control groups suggests that IGT impairment in violent and non-violent attempters was independent of affective disorder and
may represent a cognitive vulnerability for suicide. When substance abusers in both suicide groups and subjects on prescribed medication were removed from the analysis, similar findings prevailed. Moreover, Jollant et al. found that IGT scores were unrelated to age, education, intelligence, age at first attempt, number of attempts, or severity of intent. IGT scores for all groups did not correlate with behavioural impulsivity, but they did correlate positively with affective lability. Nonetheless, IGT performance in non-violent attempters, (possibly similar to the self-harm behaviour of BPD) was associated with anger expression and hostility.

Malloy-Diniz et al. (2007) found that Bipolar I outpatients with prior suicide attempts performed more poorly on the IGT than did Bipolar I controls without suicide attempt history. IGT performance was negatively related to the number of previous suicide attempts. Despite the poor EF performance of all bipolar patients when compared to healthy controls on measures of memory, attention, and set shifting, only patients with suicide attempt history performed poorly on the IGT. All subjects were matched on age, education, and IQ, although medication was not controlled for ethical reasons. Although preliminary, these findings suggest the possibility of a decision-making vulnerability for suicide attempt, which appears to exist beyond psychiatric diagnoses.

The Current Study

The primary purpose of this investigation is to compare relevant cool EF and hot IGT performance in adult women with BPD and healthy controls, to examine the relationships among estimates of working memory, interference control, motor inhibitory control, and net IGT decision making. Comprising the total study sample, this analysis has been described in Manuscript 1 (Chapter 4). A second research interest was pursued in an exploratory analysis restricted to the BPD sample only (Manuscript 2, Chapter 5) to examine the potential relationships between a variety of EFs, including IGT performance, and the prediction of total suicidal risk as measured by the Suicidal Behaviour Questionnaire – Revised (SBQ-R) (Osman et al., 2001), the primary outcome variable. In addition to the primary outcome analysis in Manuscript 2, a secondary analysis of the executive functions that best predicted the unique behavioural items comprising the total suicidal risk scores was also conducted.

Contributions of the present study. Given that (1) no prior study of IGT performance has been conducted using an all female BPD outpatient sample, (2) this is the first BPD study to
Examine relationships among this specific combination of cool EFs and hot IGT performance, and (3) this is a first exploration of a link between a variety of executive functions and suicide risk in BPD, this thesis makes an original contribution to support or refute the separability of cool EFs from emotional IGT decision making in women with BPD. The question of whether a decisional vulnerability for greater suicide risk exists in women with BPD is also explored. Study findings may have important treatment implications and improve our understanding of the homogeneity of suicidal risk in BPD and, possibly, other at-risk populations.

**Present study objectives.** This study therefore addressed four primary study objectives:

1) To compare IGT decision making and other executive function performance believed to affect IGT performance in women with BPD;

2) To examine the relationships among “cool” EFs (working memory and cognitive and motor inhibitory control), IQ, and “hot” IGT decision making;

3) To identify the EF that best distinguishes BPD subjects from healthy controls; and

4) To explore the relationships among “hot” EF, “cool” EFs, and suicide risk in women with BPD.

Four major hypotheses were tested in this preliminary investigation:

- **Hypothesis 1:** Relative to healthy controls, women with BPD will perform more disadvantageously on the Iowa Gambling Task (IGT).

- **Hypothesis 2:** Iowa Gambling Task performance will be independent of IQ, working memory, inhibitory, and interference control, as supported by the Somatic Marker Hypothesis of decision making.

- **Hypothesis 3:** IGT decision making will predict BPD status.

- **Hypothesis 4:** In addition to depression, IGT decision making will predict suicide risk in women with BPD.
Chapter 3: Methods, Measures, and Preliminary Analyses

This chapter is organized into three sections. The first section provides an overview of the study design and sampling frame and a description of the measures selected to test the research hypotheses. Section two provides additional descriptive details of the sample characteristics. The third section highlights the preliminary analyses that lead to the primary outcome analyses. Evidence of test assumptions being met and the selection of variables for the primary outcome analyses are described. Tables of the preliminary analyses, absent from both manuscripts, are included (Tables 3.1 through 3.11). This chapter illustrates, in greater detail than that required of submitted manuscripts, aspects of the research design, the sampling frame, the study instrumentation, and preliminary data screening and analyses.

This investigation compared decision making as measured by Iowa Gambling Task (Bechara, 1994) performance in adult women with BPD and healthy controls and assessed the degree to which IGT performance could be explained by other executive functions. The executive functions most strongly associated with a diagnosis of BPD and the suicidal risk that characterizes the disorder were also explored.

Methods

Research Design

This investigation utilized a quantitative, non-experimental, descriptive, cross-sectional design involving two non-equivalent groups. Non-experimental designs, such as the one chosen, while less rigorous, involve variables not within the control of the researcher, but rather, they examine traits or characteristics that occur naturally. Thus, outcomes may not be due to the selected variables under study and, therefore, require the researcher to consider alternative explanations and conclusions without definitive causal inference. Descriptive research describes phenomena with explanatory or predictive elements, typically grounded in prior theory, that incorporate other variables to explain their occurrence in a population. The Somatic Marker Hypothesis (SMH) of emotional decision making (Damasio et al., 1994) was considered theoretically relevant to the present study’s purposes and objectives and guided the interpretation of the findings.
Non-experimental designs must guard against any inference of causality as requirements for causality involve three necessary conditions. First, the two variables must be related in a linear relationship. If not, one cannot cause the other. Differences in X must be associated with differences in Y. Second, changes in X must occur before observed changes in Y. Establishing a cause occurring before an effect needs to be documented or logically explained in non-experimental designs. Finally, the third condition is that there is no possible alternative explanation for the relationship between X and Y. In other words, no third variable can explain the observed relationship between X and Y possibly having caused both.

**Sampling Frame**

BPD subjects were recruited from a clinical treatment trial examining the effectiveness of General Psychiatric Management versus Dialectical Behaviour Therapy for BPD at two downtown Toronto teaching hospitals. BPD subjects completed the active treatment phase of the treatment trial and were involved in study follow-up where they were approached and advised of the current cognitive study. Healthy controls were recruited primarily via advertising at two university sites. Interested participants were screened by telephone for study eligibility. Of the interested BPD participants, four did not meet eligibility criteria. Eighty-three eligible participants were recruited and tested during an eleven month period from February 2008 and January 2009. Convenience sampling, while fraught with biases, was considered appropriate for exploratory research, but it may not generalize to the larger population (Burns & Grove, 2005). Used with reasonable knowledge and care to reduce bias to the extent possible, convenience sampling is useful for exploratory purposes (Kerlinger, 1986).

**Sample Size**

Because IGT decision making had not been previously tested in an all-female BPD sample (recall that females perform more poorly on the IGT than males do) and considering the potential for greater stability in a recently treated outpatient sample, a moderate effect size of .35 in decision making differences among groups was anticipated. An a priori calculation of sample size to ensure sufficient power for multiple regression analyses was based on the following parameters: an effect of .35, with a maximum of five predictors, set at an alpha level of .05 and a power level of .8, resulted in the need for 84 subjects (danielsoper.com). The present sample constituted 83 subjects, but six subjects had missing data. While not ideally powered, the
final sample size did exceed the ratio of 10 subjects per independent variable as recommended (Norman & Streiner, 2008).

Measures

Dependent Variables

Iowa Gambling Task (IGT) (Bechara et al., 1994). The computerized version of the IGT involves an unspecified series of 100 card selections from one of four decks with predetermined gains and losses to maximize a loan of $2,000 in play money. In two decks (A and B), immediate gains are large but at unpredictable points; a gain is followed by an even higher penalty so that, in the long run, these decks are disadvantageous. In Decks C and D, the immediate gains are smaller but losses are also smaller so that, in the long run, these decks are advantageous. To increase the uncertainty of decision making, one of the advantageous and disadvantageous decks also carries more frequent but smaller punishments. As the task progresses, the schedules of reward and punishment are preset so that the discrepancy between reward and punishment in the disadvantageous decks becomes increasingly larger in a negative direction for every 10 cards. The discrepancy between reward and punishments in the advantageous decks become larger in the positive direction. For every 10 cards, the gains in deck A and B average $100, but the losses average $1,250, with a net loss of $250. In Decks C and D, the average gain was $50, with average losses of $250 per 10 cards resulting in an average net gain of $250 per 10 cards.

Decks appear face down on the computer screen. Using the computer mouse, the subject selects a card from any preferred deck and the computer tracks the sequence of cards selected. Subjects are warned that some decks are worse than others and that they should avoid the worst decks. Subjects were uninformed of the task duration. Immediately following each selection, the computer generates a distinct sound similar to a slot machine. The face of the card appears and a message displays indicating the amount of money won or the amount won and lost. There are no selections in which only losses occur. Each selection is tracked by a green and red bar at the top of the screen depicting the respective wins and losses and the amount remaining from the initial loan. Wins are accompanied by a happy face and a loud tone. A frown with a quieter tone accompanies the punishing card selections. The interval between each selection was preset at the
default of 500 ms. Each deck contains 60 cards. Net IGT performance, the primary variable of interest, consisted of the total number of disadvantageous cards subtracted from the total advantageous selections \[ (C + D) - (A + B) \] where higher scores represent advantageous performance. Net scores of 10 or more indicate normal performance (Bechara et al., 2001). Intermediate IGT scores were also calculated for each of five blocks of 20 cards to assess the learning that occurred as the task progressed.

Table 3.1

<table>
<thead>
<tr>
<th>Deck</th>
<th>Average Wins ($)</th>
<th>Average Losses ($)</th>
<th>Punishment Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>80 – 130</td>
<td>150 – 350</td>
<td>(5/10 cards)</td>
</tr>
<tr>
<td>B</td>
<td>80 – 160</td>
<td>1250 – 2500</td>
<td>(1/10 cards)</td>
</tr>
<tr>
<td>C</td>
<td>40 – 95</td>
<td>25 – 75</td>
<td>(5/10 cards)</td>
</tr>
<tr>
<td>D</td>
<td>40 – 95</td>
<td>250 – 350</td>
<td>(1/10 cards)</td>
</tr>
</tbody>
</table>

The IGT is resistant to changes involving the use of real money or play money (Bowman & Turnbull, 2003), manual versus computerized versions (Bechara, Tranel, & Damasio, 2000), or variations in time delays between card selections (Bowman, Evans, & Turnbull, 2005). It has proven reliable in ventromedial patients following numerous administrations where improvements do not occur with practice or prior exposure, as is demonstrated in healthy control groups. The IGT is considered an ecologically valid measure of decision making in numerous clinical populations and has demonstrated test-retest reliability in neurological patients; however, its content validity has been questioned recently due to the lack of a concise definition of which aspect of decision making it measures, an absence of reliability data in psychiatric populations, and the influence of personality and negative mood on performance (Buelow & Suhr, 2010).

To support the interpretation of the IGT deficits as representing a myopia of the future, two modified versions of this task were administered to ventromedial lesioned patients (Bechara et al., 1998). In the first modification, the reward and punishments were reversed so that differences in reward were the optimal response. In other words, the advantageous decks yielded higher immediate punishment but even greater delayed reward, while the disadvantageous decks provided low immediate punishment but even lower future reward. Performance on this version suggests that impairment was unrelated to a sensitivity to either punishment or reward. In the second variant, the adverse future consequences associated with
the risky decks was increased. Despite increasing the *delayed* punishment and decreasing the reward on the disadvantageous decks, lesioned patients were also impaired on this task relative to controls (Bechara et al., 2000b).

**Suicide Behaviour Questionnaire, Revised (SBQ-R) (Osman et al., 1998).** This forced choice self-report assesses lifetime suicide related thoughts and behaviours. It represents a shorter version of the original Suicide Behaviour Questionnaire that was developed for BPD subjects (Linehan, 1981), and it is recommended for research and clinical purposes (Cotton et al., 1995). Osman et al. (2001) examined the reliability and validity of the SBQ-R in clinical and non-clinical undergraduate samples. A cut of eight has 87% sensitivity and 93% specificity for suicidal inpatient samples. For non-clinical samples, a cut of seven demonstrates excellent sensitivity (83%) and specificity (96%). Each of the four items comprising the overall score assesses a different dimension of suicidal behaviour. Item 1 taps into lifetime suicide ideation and/or suicide attempts (scored 1 to 4). Item 2, rated from 1 to 5, assesses the frequency of suicidal ideation in the previous 12 months. Item 3 quantifies the threat of suicide attempt with scores rated from 1 to 3. The self-reported likelihood of future suicide behaviour is the fourth item, which ranges from never (0) to very likely (6). Total scores ranging from 3 to 18 represent overall suicide risk, which is the primary dependent variable; higher scores represent greater risk. The Cronbach alpha coefficient of internal consistency among the four items of the SBQ-R scale was .90 in the present sample. Because the determination of suicide risk is considered more valid when using subjective measures (Soloff et al., 2000), this instrument was considered appropriate for this exploratory analysis.

**Independent Measures of Cognitive Task Performance**

**Digit Span (Weschler, 1997).** The Digit Span is one of the tasks comprising the verbal component of the Weschler Adult Intelligence Scale – Revised (WAIS-R) (Weschler, 1997), which targets verbal working memory capacity. The Digit Span consists of two tasks administered independently of each other. On both tasks, the examiner reads aloud a series of number sequences of increasing difficulty. Forward recall assesses short-term storage or basic memory and reverse recall assesses both the storage and reorganization of information. For each forward item, the subject repeats the number sequence in the same order presented. Digits backward requires the repetition of the number sequence in the reverse order. Each sequence
length (ranging from 4-8 digits) has two trials with each trial consisting of the same number of digits. Two points are awarded for correct responses on both trials of a sequence length. One point is awarded if only one trial of a sequence length is correct. If both trials are incorrect, zero points are given and the test is discontinued. A maximum total of 30 points is possible, 16 points for forward recall and 14 for backward recall. The total Digit Span score was the variable of interest where higher scores represent improved working memory. Performance was also compared to the standardized norms for the Canadian sample of 30- to 34-year-olds (Wais-III, 1997). The Digit Span is frequently used as an estimate of verbal working memory in cognitive and neuropsychological research. Internal consistency scores are the highest for all verbal subtests of the WAIS (.97) with test-retest coefficients of .94 to .97 for the Digit Span (Strauss, Sherman, & Spreen, 2006).

**Victoria Stroop Test (Regard, 1981).** The Victoria Version of the Stroop test (VST) (Regard, 1981) is a short and psychometrically sound version of the original Stroop (Golden 1935) that assesses the ability to control interference and response conflict. Stroop tasks are also believed to recruit elements of selective attention, interference from distraction, and cognitive flexibility (Henik & Salo, 2004). The VST consists of three reaction time conditions, consisting of 24 items for each condition arranged on separate pages containing six rows of four items. Quickly scanning the pages from left to right, participants name the colour of 24 rectangles without making errors. The second condition is a test of reading speed, which requires rapid, accurate reading of non-coloured words printed in black ink. The third condition, the incongruent condition, requires participants to name the ink colour of incongruently coloured words (i.e., the word “red” is printed in blue ink and the participant must repress the urge to say red). Naming the ink and suppressing the automatic urge to read the word requires considerable effort because reading is over-learned and automatic. Reaction time is measured in seconds where longer time represents poorer interference control. Interference scores, which account for baseline processing speed, are calculated. If baseline slowing is suspected to be due to age or other factors, the interference score is computed as a ratio of incongruent speed divided by colour naming speed (Troyer et al., 2006).

Given that cognitive slowing is suspected in women with BPD, the ratio interference score constituted the primary variable. Self-corrections are not considered errors, and in this
sample, all errors were self-corrected. Adequate reliability estimates of the VST have been demonstrated (.90 for colour naming and .91 for the incongruent condition). The VST is considered sensitive to frontal lobe damage (Spreen & Strauss, 1998) and correctly distinguishes healthy controls and psychiatric patients from brain injured patients with 87% accuracy (Spreen & Strauss, 1991). The benefits of the VST are the short administration time where extended practice is avoided (relative to the many items of the Golden version) and the calculation of interference scores that account for cognitive slowing (Troyer et al., 2006). The primary region of activation during Stroop performance is believed to be the anterior cingulate cortex (Smith & Jonides, 1999).

**Stop Task (Logan 1994).** The Stop Task measures basic motor inhibition or the ability to stop suddenly and complete a planned or ongoing thought or action (Logan, 1994). This task estimates the time required to generate this internal act of control because successful inhibition cannot be observed. Stop Signal Reaction Time (SSRT) represents the time required for stopping a behavioural response. Changes in SSRT are believed to distinguish important differences among impulsive and non-impulsive adults (Logan et al., 1997).

The Stop Task is a computerized dual paradigm task in which a target “go” stimulus (an X or an O) is displayed on the monitor. Using the computer mouse, participants must respond as quickly as possible to each go signal by pressing the right mouse button when an X appears and the left mouse button when an O appears. Subjects must withhold this response when they hear a distinct auditory tone, which occurs on approximately 25% of the trials. This tone sounds at variable delays following the go command, and it is referred to as the Stop Signal Delay or SSD (the interval between the onset of the go and the onset of the stop). SSD was pre-programmed at 250 milliseconds initially. After a successful stop, the SSD was increased by 50 ms., making it harder to inhibit on the next trial. After a failed stop, SSD was decreased by 50 ms., making it easier to inhibit. This tracking or titration method results in a 50% successful inhibition rate, which represents an individual’s average ability to stop and is considered a valid parameter to estimate SSRT (Band, van der Molen, & Logan, 2003). Stop Signal Reaction Time (SSRT) is the difference between the mean “go” reaction time and the average SSD. SSRT is the primary variable in which longer RT represents weaker inhibition (Logan, 1994). SSRT has been assessed for age-related differences in normal Canadian control subjects (Williams et al., 1999) and is considered a valid measure of the motor dimension of inhibitory control.
Standard Progressive Matrices (SPM) (Raven, Raven, & Court, 2000). The Standard Progressive Matrices (SPM) measures a person’s ability to form perceptual relations and to reason by analogy that is independent of language and formal schooling. The SPM is a test of inductive reasoning and is the first and most widely used of three instruments known as the Raven’s Progressive Matrices, which measure general intelligence. According to Spreen et al., (2006) subjects must infer a rule relating to the collection of visual elements, and then use the rule to generate the next item in a series of items that become increasingly more difficult. The earlier items serve as a learning experience for the later more complex items. This test is popular because it assesses the participant’s ability to become more efficient by learning from immediate experience. Responses on this task do not require verbalization, skilled manipulation ability, or subtle differences in visuospatial information processing. Visuospatial processing has been described as a deficit in some BPD subjects (O’Leary et al., 2000; Monarch et al., 2004).

The SPM consists of 60 visual items arranged in five sets of 12 items each. Each item contains a figure with a missing piece. Below the figure are either six or eight alternative pieces to complete the figure, only one of which is correct. Each set involves a different principle for obtaining the missing piece, and within a set, the items are arranged in increasing difficulty. Participants work at their own pace and are given a practice trial at the beginning to ensure all instructions are understood. Typically, this task requires 40 minutes to complete. Internal consistency values range from .60 to .98, with a median of .90. Test-retest correlations range from .46 for an eleven-year interval to a high of .97 for a two-day interval. The median test-retest value is approximately .82 (Strauss et al., 2006). Spearman considered the SPM to be the best measure of general intelligence (Strauss et al., 2006). Because this test requires novel problem solving, it is considered a measure of fluid intelligence. The majority of studies that have factor analyzed the SPM with other cognitive measures in Western cultures report loading higher than .75 on a general intelligence factor. The majority of concurrent validity coefficients between the SPM and the Stanford-Binet and Weschler intelligence scales range in the .70s and .80s (Strauss et al., 2006).

Independent Variables: Clinical Measures

The McLean Screening Instrument for BPD (MSI-BPD) (Zanarini et al., 2003). This self-report screen assessed the currency of BPD pathology, and it is based on questions
comprising the borderline module of the Diagnostic Interview for DSM-IV Personality Disorder (American Psychiatric Association, 1994). One item assessed eight of nine DSM –IV criteria, with two items assessing the ninth criteria of paranoia and dissociation. Each item is worth one point on a scale from 0 to 10. A score of 7 or more has both high sensitivity (.81) and specificity (.85) for BPD. The diagnostic efficiency of the MSI-BPD improved with subjects aged 30 or under, with a sensitivity of .87 and specificity of .90. For those younger than 25 years, sensitivity increased to .90 and specificity to .93.

**Attention Deficit Scale for Adults (Triolo & Murphy, 1996).** The Attention Deficit Scale for Adults (ADSA) consists of 54 items that directly or indirectly address symptoms associated with Attention Deficit/Hyperactivity Disorder (ADHD). Each subject endorses one of five categories for each item (never, seldom, sometimes, often, or always). Most items are worded so that “never” does not suggest an ADHD problem and “always” suggests a significant ADHD related problem. Eleven of the 54 items, however, are reversed. Total ADSA raw scores were used in the present study with total scores of 181, representing moderate to severe ADHD symptoms (Triolo & Murphy, 1996). A score beyond two SDs suggests serious problems of ADHD symptoms. Although the DSM-IV criteria for ADHD are more sensitive than previous editions, they remain geared to children and adolescents. Items on the ADSA were developed to be sensitive to adults with ADHD, as few DSM-IV symptoms can be applied to adults (Triolo & Murphy, 1996). The ADSA scale is currently recommended as a research screening tool. This scale has successfully discriminated BPD subjects from ADHD subjects (Dowson et al., 2004). Triolo & Murphy (1996) tested this measure using comparison data from 305 individuals with a mean age of 34 years, an IQ of 80, no substance abuse history, and no history of attention or hyperactivity problems. Test validity was assessed in 97 clinical subjects previously diagnosed with ADHD, 82% of whom were classified correctly.

**Test of Word Reading Efficiency (TOWRE) (Torgesen, Wagner, & Rashotte, 1999).** The TOWRE screen indexes reading ability involving the number of words read quickly and accurately and pronounced correctly in 45 seconds. Lists of words were presented in columns and participants must read the words from top to bottom until instructed to stop. If participants could not read a word, they were instructed to move on quickly to the next word. All subjects received a practice trial on both sub-tests. A standardized reading efficiency score constituted
the primary variable and was based on sub-test performance. Raw scores for each sub-test were converted using tables representing U.S. norms for individuals with 12 to 12.9 years of education (Torgesen et al., 1999). The standardized scores for sub-tests and total scores represented a mean of 100 and a SD of 15. Percentile ranks were also examined. This instrument is sensitive to more complex reading tasks, minimizes the effects of culture and ethnicity, and screens for possible learning disability in adults. Reliability coefficients exceed .90. Test-retest reliability coefficients for total word reading efficiency scores are .93. Concurrent validity coefficients with other valid measures of reading are .91 and .92 (Torgesen et al., 1999).

**Beck Depression Inventory II (BDI) (Beck et al., 1996).** This 21-item self-report instrument was designed to assess depression severity in adolescents and adults during the preceding week. Items are rated from 0 (absence of symptoms) to 3 (severe symptoms), with totals ranging from 0 to 63. Higher scores indicate more depression. Adequate reliability and validity have been reported with clinical and non-clinical samples (Al-Musawi, 2001; Arnau et al., 2001; Dozois et al., 1998).

**Beck Anxiety Inventory (Beck & Steer, 1993).** The Beck Anxiety Inventory (BAI) is also a 21-item self-report instrument, but it assesses how the patient felt in the preceding month. Each question is scored from 0 (not at all) to 3 ("it bothered me a lot") for a maximum of 63 points. Scores of 1-21 indicate low anxiety, scores of 22-35 represent moderate anxiety, and those exceeding 36 are considered a potential cause for concern. Similar to the BDI, this measure is not diagnostic, but it does provide an estimate of current states of anxiety. The internal consistency coefficient of the BAI is .92 and the test-retest reliability is .75 in medical outpatients (De Ayala et al., 2005).

**The Borderline Evaluation of Severity over Time (BEST) (Pfohl & Blum, 1997).** The BEST is a self-rating scale assessing BPD severity within the preceding seven days. Recent thoughts and feelings and negative and positive behaviours are rated on a five-point scale (1 = none/slight and 5 = extreme or almost always). The scale includes 15 items and three subscales.Eight items comprise thoughts and feelings (A), and four items comprise negative behaviour (B) rated as 1 to 5. The final three items comprise positive behaviour (C) rated from 5 (almost always) to 1 (almost never); scores are reversed for positive behaviour. The final score consists
of the totals of A and B, minus subscale C scores. A correction factor of 15 is added to yield the final score, which can range from 12 (best) to 72 (worst). This scale demonstrates excellent alpha internal consistency coefficients of .86 to .92 with BPD and non-BPD comparison subjects at one month following treatment (.89) and at five-months following treatment (.92). Test-retest reliability is lower (0.60) as assessed during a 46-day interval of treatment. The BEST correlates strongly with both the ZAN BPD score and the SCL-90-R total score, and it is sensitive to clinical change (Pfohl et al., 2009).

**Procedures**

All measures were administered individually in a single session lasting three to four hours. Instructions for all tasks were standardized and scripted. To lessen the emotional effect on task performance and to ensure blinding to current suicidal status, performance tasks preceded self-report measures. A clinician/PhD trainee administered measures to 76 participants and a trained research assistant administered measures to seven controls. Depression, anxiety, and suicidal measures were administered to all participants. Co-morbidity and medication data were acquired through self-reporting. BPD participants completed measures without obvious distress. All participants received a full written description of the study, provided written consent, and received a nominal fee for the completion of measures. Raw data was analyzed using SPSS version 13. Due to the exploratory nature of this investigation and the number of variables relative to the existing sample size, total scores of each executive function estimate were utilized in the final outcome analyses.

**Preliminary Analyses**

**Data Screening**

Initial data screening included assessment for (1) data accuracy, (2) missing data, (3) outliers and extreme scores, and (4) ensuring that the assumptions of normality were met.

**Errors/Omissions**

An audit of the complete data set was manually compared to the raw data for accuracy. Frequency distributions and raw scores were examined. Missing or incomplete data varied among measures and groups. As a result of unexplained computer error, four controls had partially missing SSRT data. One case subject had missing IGT data due to computer error.
Two case subjects completed neither BDI nor suicide data for unknown reasons. These omissions and errors were not known on the day of testing and no attempt was made to follow up with subjects in this regard.

**Outliers**

Each variable was checked for outliers and extreme scores using visual inspection of the histograms and boxplots. No outliers or extreme scores were evident for either dependent variable (net IGT and SBQ R). However, three outliers for IQ (left skew) were evident in the total sample. One case and one control subject were deemed to be multivariate outliers on the basis of their outlying scores on three different measures. Repeat statistical analyses excluding the two multivariate outlier subjects produced no differences in the overall findings, such that all subjects with complete data were included in the final analyses.

**Assessment of Normality**

Normality of distributions must be assumed for all parametric analyses. Assumptions of normality were assessed separately for the total sample and the BPD sample. Kolmogorov-Smirnov (KS) Z tests assessed the significance of skew. These results are summarized in Table 3.2 and Table 3.3. The KS Z score for IQ in the total sample was significant ($Z = 1.49; p = 0.024$), thus requiring an inverse transformation. Transformed Matrices (IQ) scores were rechecked with repeat histograms and KS analyses, and they demonstrated a more normal distribution. The KS Z tests in the BPD sample (Table 3.3) indicated that Stroop interference demonstrated a positive skew ($Z = 1.42, p = 0.037$), resulting in a log transformation of this variable for analyses with BPD subjects only. The primary analyses were completed using the raw scores for all variables except the two transformed variables. Interpretations of the transformed variables were guided by the analyses using untransformed variables. The use of transformed IQ data in the total sample increased the adjusted variance in net IGT performance by 2%.
Table 3.2
One Sample Kolmogorov-Smirnov Test for Assessment of Normality of Distributions (Total Sample)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit span</td>
<td>83</td>
<td>0.807</td>
</tr>
<tr>
<td>Raven’s matrices (IQ)</td>
<td>83</td>
<td>1.490*</td>
</tr>
<tr>
<td>Net IGT</td>
<td>82</td>
<td>0.664</td>
</tr>
<tr>
<td>SSRT</td>
<td>80</td>
<td>0.804</td>
</tr>
<tr>
<td>Stroop interference (cw/c)</td>
<td>83</td>
<td>1.247</td>
</tr>
<tr>
<td>Raven matrices transformed</td>
<td>82</td>
<td>0.837</td>
</tr>
</tbody>
</table>

Asymp. Sig (2-tailed) = skewness; * p = <.05,
Digit Span = working memory; Raven’s = IQ; IGT = decision making; SSRT = response inhibition; Stroop = interference control.

Table 3.3
One Sample Kolmogorov-Smirnov Test for Normality of Distributions of scale scores for the BPD sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit span</td>
<td>41</td>
<td>0.706</td>
</tr>
<tr>
<td>Net IGT</td>
<td>41</td>
<td>0.611</td>
</tr>
<tr>
<td>Raven’s matrices</td>
<td>42</td>
<td>1.082</td>
</tr>
<tr>
<td>SSRT</td>
<td>42</td>
<td>0.936</td>
</tr>
<tr>
<td>Stroop interference (cw/c)</td>
<td>42</td>
<td>1.415*</td>
</tr>
<tr>
<td>BDI</td>
<td>42</td>
<td>0.642</td>
</tr>
<tr>
<td>TOWRE(z)</td>
<td>42</td>
<td>0.616</td>
</tr>
<tr>
<td>ADSA</td>
<td>42</td>
<td>0.873</td>
</tr>
<tr>
<td>SBQ-R total</td>
<td>40</td>
<td>0.954</td>
</tr>
<tr>
<td>Stroop interference transformed</td>
<td>42</td>
<td>0.757</td>
</tr>
</tbody>
</table>

asympt. (2 –tailed) * p<.05

Sample Characteristics

BPD and healthy controls were similar in age, marital status, and Canadian-born status. All subjects were 21 to 51 years of age with their education spanning 9 to 25 years. Relative to controls, BPD women had significantly fewer years of education, tended to live alone, and were less frequently employed on a full-time basis. Nine women with BPD were unemployed and not seeking employment, whereas no control participant fit these criteria. Groups were similar in their part-time working or part-time student status. BPD subjects completed an average of 13.5 years of education while controls completed 15.6 years. Despite the statistical differences in education, both groups were considered to be generally well educated. The more highly educated controls may have been the result of a recruitment bias, which occurred primarily at
two post-secondary education sites. Not unexpectedly, groups differed in their depression/anxiety scores and treatment histories. Fifty percent of the BPD participants experienced a prior history of substance abuse, and 76% were stabilized on psychotropic medications. Twenty-four percent (10/42) of the BPD sample were unmedicated. Nine BPD subjects were taking anti-depressants alone. The majority (31% or 13/42) were currently prescribed antidepressants and anti-anxiety medications. In addition to antidepressants and anti-anxieties, five BPD subjects (11.9%) were also prescribed neuroleptics, and another five were taking anticonvulsants in addition to a mix of neuroleptics, anti-anxiety, and antidepressant medications.

Table 3.4 provides a frequency comparison of the sample characteristics. The mean depression and anxiety scores for the BPD group were within the moderate range of severity. Fifty-seven percent of BPD women rated their depression as normal to moderate. Seventy-two percent of women with BPD rated their anxiety as mild to moderate. Sixty-three percent of BPD women performed poorly on the IGT (net scores of <10). The median net IGT score in the BPD group was 4, and the mode was 8. Net IGT scores ranged from -84 to 48. In contrast, reverse patterns of IGT performance were present in the healthy controls where 36.6% performed poorly on the IGT and 63% performed normally. The median net IGT score for the control group was 18, the mode was 10. Based on prior research, approximately 30-35% of normal samples typically perform disadvantageously on the IGT (Dunn et al., 2006). The slightly higher rate in our healthy controls may be the result of higher education, which is believed to discourage or limit intuitive thinking (Evans et al., 2004) and the female sample. Groups also differed significantly on their reading and attention deficit scores. The mean ADSA scores of the BPD group did not reach the threshold indicative of moderate to severe adult ADHD; however, 43% of BPD participants had individual scores exceeding this cut (>181). It remains unclear whether reading ability, slower reading, slower processing, or negative affect in general may have contributed to below normal reading performance (17th percentile of population norms) in BPD women.

The mean suicidal risk score (SBQ-R) exceeded the cut of eight deemed to be indicative of suicide risk (M = 13.3, SD = 3.5; Median = 14; Mode 16) in BPD women. Mean suicidal scores for the healthy controls were 3.78 (SD = 1.3), with a median of 3 and a mode of 3. Three is the minimum score on the SBQ-R representing an absence of suicidal risk. All women with
BPD reported a history of self-harm behaviour primarily involving cutting and burning. Sixty-seven percent (26/42) reported lifetime histories of suicide attempts, ranging from one to seven attempts, with only 14/42 (33%) reporting suicide attempts within the previous year, most frequently involving one to three attempts. Ninety percent (36/40) of the BPD sample were deemed to be at risk for suicide based on their total SBQ-R scores >8.

Table 3.4

<table>
<thead>
<tr>
<th>Measures</th>
<th>BPD</th>
<th></th>
<th>Healthy Controls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor Net IGT (&lt;10)</td>
<td>26</td>
<td>63.4</td>
<td>15</td>
<td>36.6</td>
</tr>
<tr>
<td>BDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal (5-9)</td>
<td>6</td>
<td>14.3</td>
<td>32</td>
<td>78.0</td>
</tr>
<tr>
<td>Mild (10-18)</td>
<td>8</td>
<td>19.0</td>
<td>7</td>
<td>17.1</td>
</tr>
<tr>
<td>Moderate (19-29)</td>
<td>10</td>
<td>23.8</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Severe (30-63)</td>
<td>18</td>
<td>42.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BAI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild (0-21)</td>
<td>20</td>
<td>47.6</td>
<td>39</td>
<td>78.0</td>
</tr>
<tr>
<td>Moderate (22-35)</td>
<td>10</td>
<td>23.8</td>
<td>2</td>
<td>4.9</td>
</tr>
<tr>
<td>Severe (36-60)</td>
<td>12</td>
<td>38.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ADSA &gt;181</td>
<td>18</td>
<td>42.8</td>
<td>2</td>
<td>4.9</td>
</tr>
<tr>
<td>Education (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-12</td>
<td>20</td>
<td>47.6</td>
<td>7</td>
<td>17.1</td>
</tr>
<tr>
<td>13-20</td>
<td>22</td>
<td>52.4</td>
<td>32</td>
<td>78.0</td>
</tr>
<tr>
<td>21-25</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4.9</td>
</tr>
<tr>
<td>SBQ-R&gt;8</td>
<td>36</td>
<td>90.0</td>
<td>1</td>
<td>2.4</td>
</tr>
</tbody>
</table>

ADSA >181 = moderate-severe ADHD symptoms
SBQ-R >8 = denotes presence of suicidal risk
Net IGT <10 = disadvantageous decision making.

Table 3.5 depicts significant group mean differences of total IGT selections on three of the four card decks (Decks B, C, and D). Mean group differences on Deck A selections also trended toward significance \( p = 0.06 \), supporting the decision to utilize the net IGT score as the primary dependent variable. Groups did not differ significantly in the card selections that varied by high (Decks A and C) or low frequencies of punishment (Decks B and D). The initial significant group differences in total and backward working memory and all Stroop baseline and interference difference (iii-i) scores became non-significant when education was controlled.

\[ \text{Total working memory } F(2,82) = 1.87, p = .18; \text{ Stroop colour reading: } F(2,82), = 1.81, p = .18; \]
\[ \text{Stroop word reading } F(2,82), = 1.84 p = .18; \text{ Stroop incongruent colour/word, } F(2,82) = 3.31, p \]
= 0.07 and Stroop interference differences scores $F(3, 79) = 2.33, p = .13$. Stroop ratio scores (iii/i), IQ, and response (motor) inhibition scores, while weaker than controls, did not differ significantly among groups with or without control for education. Because IQ differences trended toward significance ($p = 0.08$), IQ was considered a potential confound of EF performance.

Table 3.5
Unadjusted Mean Differences in IGT, EF and IQ Performance in Women with BPD and Healthy Controls

<table>
<thead>
<tr>
<th></th>
<th>BPD Mean (SD)</th>
<th>N</th>
<th>Healthy Controls Mean (SD)</th>
<th>N</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGT Selections/100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck A (Disadv)</td>
<td>15.90 (6.5)</td>
<td>41</td>
<td>13.40 (5.2)</td>
<td>41</td>
<td>.058</td>
</tr>
<tr>
<td>Deck B (Disadv)</td>
<td>33.26 (14.7)</td>
<td>41</td>
<td>26.05 (12.3)</td>
<td>41</td>
<td>.018</td>
</tr>
<tr>
<td>Deck C (Adv)</td>
<td>19.98 (8.0)</td>
<td>41</td>
<td>23.34 (13.4)</td>
<td>41</td>
<td>.029</td>
</tr>
<tr>
<td>Deck D (Adv)</td>
<td>30.48 (14.7)</td>
<td>41</td>
<td>37.20 (14.5)</td>
<td>41</td>
<td>.040</td>
</tr>
<tr>
<td>Net IGT</td>
<td>-.71 (30.2)</td>
<td>41</td>
<td>21.07 (30.3)</td>
<td>41</td>
<td>.002</td>
</tr>
<tr>
<td>A+C</td>
<td>33.85 (11.4)</td>
<td>41</td>
<td>36.76 (13.2)</td>
<td>41</td>
<td>.292</td>
</tr>
<tr>
<td>B+D</td>
<td>63.74 (14.3)</td>
<td>41</td>
<td>63.24 (13.2)</td>
<td>41</td>
<td>.870</td>
</tr>
<tr>
<td>Digit Span Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>16.54 (3.9)</td>
<td>42</td>
<td>18.56 (4.2)</td>
<td>41</td>
<td>.041</td>
</tr>
<tr>
<td>Back</td>
<td>10.23 (2.3)</td>
<td>42</td>
<td>11.00 (2.4)</td>
<td>41</td>
<td>.155</td>
</tr>
<tr>
<td>SSRT</td>
<td>256.33 (93.6)</td>
<td>42</td>
<td>233.77 (55.1)</td>
<td>38</td>
<td>.199</td>
</tr>
<tr>
<td>Raven’s Matrices</td>
<td>46.80 (11.0)</td>
<td>42</td>
<td>50.44 (7.0)</td>
<td>41</td>
<td>.078</td>
</tr>
<tr>
<td>Stroop (sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Color</td>
<td>13.21 (4.5)</td>
<td>42</td>
<td>11.38 (2.2)</td>
<td>41</td>
<td>.022</td>
</tr>
<tr>
<td>ii) Word</td>
<td>10.23 (3.7)</td>
<td>42</td>
<td>8.60 (1.6)</td>
<td>41</td>
<td>.021</td>
</tr>
<tr>
<td>iii) Color/Word</td>
<td>26.78 (11.9)</td>
<td>42</td>
<td>21.17 (4.3)</td>
<td>41</td>
<td>.006</td>
</tr>
<tr>
<td>Interference (iii-i)</td>
<td>13.57 (9.0)</td>
<td>42</td>
<td>9.77 (4.3)</td>
<td>41</td>
<td>.018</td>
</tr>
<tr>
<td>Interference (iii/i)</td>
<td>2.02 (0.62)</td>
<td>42</td>
<td>1.91 (.47)</td>
<td>41</td>
<td>.342</td>
</tr>
</tbody>
</table>

A+C = decks of high frequency punishment
B+D = decks of low frequency punishment
Net IGT = (C + D) – (A + B)/100 card selections

While control for education eliminated working memory and Stroop interference group differences, adjustment for education did not alter the net IGT differences among groups, $F(3.79) = 6.92, p = .01$. When ANCOVAs were rerun on net IGT performance, while controlling for both IQ and education entered jointly as covariates, group differences in Net IGT performance also remained significant $F(3.78) = 5.81, p = 0.02$. 
Patterns of Early and Late IGT Performance I. In addition to a determination of statistically significant differences in net IGT performance among healthy controls and women with BPD, it is recommended that patterns of IGT performance should also be examined to facilitate the interpretation of IGT deficits (Levine et al., 2005). Trends of IGT performance based on early (1st 50) and late (last 50) card selections are depicted in Figure 3.1. A pattern in BPD women of increases in Deck B (riskiest) and no changes to Deck C (safest) selections during the last 50 cards may represent a risk-seeking vulnerability or sensitivity to reward. Note that controls decreased the riskiest B selections and increased the safer C selections during the last 50 cards. However, the trend of increased selections from the infrequent punishment decks (B & D) as well as a noticeable drop in Deck A (high frequency punishment) selections could also implicate a sensitivity to or avoidance of the most frequently punishing decks (irrespective of the magnitude of punishment). BPD women’s hyper-sensitivity or arousal to the frequent punishment decks on the IGT could limit their attention to the magnitude of punishment cues on the IGT. It is not clear whether IGT decision deficits in BPD women may be due primarily to a sensitivity to reward (risk-seeking) or an avoidance of frequent punishment.
Preparation for Primary Outcome Analysis

Assessment of Linearity and Multicollinearity. Two-tailed Pearson product moment correlations and scatterplot analyses assessed the strength and direction of the relationships among the independent and the dependent variables in both studies. Multicollinearity among the independent variables was also assessed. The collinearity among all the dependent and independent variables in the total sample are presented in Table 3.6. Table 3.7 depicts the collinearity among all variables in the BPD sample and, additionally, examines their correlations with total suicide risk.
### Table 3.6
**Correlational Matrix of Independent and Dependent Variables (Total Sample)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. IGT</td>
<td></td>
<td>.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. Digits</td>
<td>.20</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. IQ</td>
<td>.43**</td>
<td>.39**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. SSRT</td>
<td>.16</td>
<td>-.22</td>
<td>-.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Stroop Ratio</td>
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<td>-.15</td>
<td>-.49**</td>
<td>.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6. Education</td>
<td>.29**</td>
<td>.25*</td>
<td>.32**</td>
<td>-.07</td>
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<td></td>
</tr>
<tr>
<td>7. BDI</td>
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<td>-.24*</td>
<td>-.22*</td>
<td>.09</td>
<td>.12</td>
<td>-.33**</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8. BAI</td>
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<td>-.04</td>
<td>.03</td>
<td>-.01</td>
<td>-.32</td>
<td>.80**</td>
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<tr>
<td>9. ADSA</td>
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<td></td>
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<tr>
<td>10. Reading</td>
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<td>.27*</td>
<td>-.14</td>
<td>-.14</td>
<td>.46**</td>
<td>-.35**</td>
<td>-.24*</td>
<td>-.27*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. McLean Screen</td>
<td>-.35**</td>
<td>-.22</td>
<td>-.19</td>
<td>.11</td>
<td>.14</td>
<td>-.37**</td>
<td>.72**</td>
<td>.63**</td>
<td>.74**</td>
<td>-.45**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. BPD Severity</td>
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<td>-.18</td>
<td>-.07</td>
<td>-.01</td>
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<td>.80**</td>
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<td>.59**</td>
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<tr>
<td>13. SBQt Severity</td>
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<td>-.18</td>
<td>-.12</td>
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<td>-.06</td>
<td>-.31**</td>
<td>.78**</td>
<td>.68**</td>
<td>.68**</td>
<td>-.33**</td>
<td>.83**</td>
<td>.57**</td>
</tr>
</tbody>
</table>

** p<.01 2 tailed; * p<.05 2 tailed

### Table 3.7
**Correlational Matrix of Independent and Dependent variables in the BPD Sample**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SBQRT</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. IGT</td>
<td></td>
<td>.02</td>
<td>.22</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3. Digits</td>
<td>-.02</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. IQ</td>
<td>.10</td>
<td>.57**</td>
<td>.47**</td>
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</tr>
<tr>
<td>5. SSRT</td>
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<td></td>
</tr>
<tr>
<td>6. Stroop cw/c</td>
<td>-.38*</td>
<td>-.33*</td>
<td>-.21</td>
<td>-.65**</td>
<td>.01</td>
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<tr>
<td>7. Education</td>
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<td>.30</td>
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<td>-.13</td>
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</tr>
<tr>
<td>8. BDI</td>
<td>.44**</td>
<td>-.07</td>
<td>-.19</td>
<td>-.10</td>
<td>-.02</td>
<td>.09</td>
<td>-.06</td>
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<td></td>
</tr>
<tr>
<td>9. BAI</td>
<td>.33**</td>
<td>-.03</td>
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<td>.26</td>
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<td>-.15</td>
<td>-.02</td>
<td>.63**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. ADSA</td>
<td>.11</td>
<td>.23</td>
<td>.14</td>
<td>.33*</td>
<td>.07</td>
<td>-.23</td>
<td>.07</td>
<td>.37*</td>
<td>.46**</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11. Reading</td>
<td>.05</td>
<td>.15</td>
<td>.49**</td>
<td>.37*</td>
<td>-.10</td>
<td>-.12</td>
<td>.43**</td>
<td>-.12</td>
<td>.06</td>
<td>.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. McLean Screen</td>
<td>.13</td>
<td>.13</td>
<td>-.26</td>
<td>-.17</td>
<td>-.02</td>
<td>.23</td>
<td>-.24</td>
<td>.22</td>
<td>.09</td>
<td>.17</td>
<td>-.36*</td>
<td></td>
</tr>
<tr>
<td>13. BPD Severity</td>
<td>.34**</td>
<td>-.05</td>
<td>-.11</td>
<td>-.04</td>
<td>-.09</td>
<td>-.05</td>
<td>.74*</td>
<td>.68*</td>
<td>.44**</td>
<td>-.04</td>
<td>.34*</td>
<td></td>
</tr>
</tbody>
</table>

** p<.01 2 tailed; * p<.05 2 tailed

**Assessing the Homogeneity of Regression Slopes.** In preparation for ANCOVA analyses, the assumption of the homogeneity of regression slopes was checked. The absence of significant interactions between groups and each covariate on decision making is presented in Table 3.8, indicating that this assumption was met. This analysis ensures that the relationship between each covariate and IGT decision making was equivalent in each group.
Table 3.8
Assessment of Interactions between Group, each Covariate and net IGT

<table>
<thead>
<tr>
<th>Interaction</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P value</th>
<th>Levine’s sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group x BDI</td>
<td>1</td>
<td>1206.23</td>
<td>1.34</td>
<td>.250</td>
<td>.870</td>
</tr>
<tr>
<td>Group x Digit span</td>
<td>1</td>
<td>532.97</td>
<td>.594</td>
<td>.443</td>
<td>.870</td>
</tr>
<tr>
<td>Group x Matrices</td>
<td>1</td>
<td>2240.17</td>
<td>3.013</td>
<td>.087</td>
<td>.222</td>
</tr>
<tr>
<td>Group x Stroop c/cw</td>
<td>1</td>
<td>1051.48</td>
<td>1.173</td>
<td>.282</td>
<td>.855</td>
</tr>
<tr>
<td>Group x SSRT</td>
<td>1</td>
<td>1412.85</td>
<td>1.680</td>
<td>.199</td>
<td>.749</td>
</tr>
</tbody>
</table>

Group = BPD vs. Healthy Controls; Digit Span = working memory; Matrices = IQ; Stroop = interference control; SSRT = motor or response inhibition, BDI = depression.

Controlling for Depression on EF Task Performance. As expected, depression scores were significantly higher in the BPD group than they were in the control group. As depression and BPD are highly co-morbid and strongly associated in this sample, it was important to examine the main effects of BPD relative to the main effects of depression on IGT performance. An ANCOVA was run with depression as the covariate, group as the independent variable, and net IGT as a dependent variable. The group differences on net IGT performance remained significant, F (2,78) = 4.89, p = 0.03. Neither main depression effects, F(2,78) = 0.693, p =.41, nor group x depression interaction effects on net decision making were significant, F (3,77) = 1.34, p = .25. There were no significant main effects of depression or group on working memory, motor inhibition, interference control, or IQ, as determined by a series of ANCOVAs with depression as a covariate, group as the between subject factor, and each EF and IQ as within subject factors.

An analysis of covariance was performed with the dependent variable IGT performance, the grouping factor BPD status, and covariates of Digits Total, Matrices (IQ), Stroop Interference, and SSRT (Table 3.9). As previously noted, the Matrices scores were inversely transformed. A preliminary analysis established that the assumption of homogeneity of regression slopes was met. The ANCOVA was significant, group (BPD) status showed significance at the .001 level. These results demonstrate that IGT decision-making deficits in women with BPD persist despite control for IQ, working memory, Stroop interference control, and motor response inhibition.
Table 3.9
Analysis of Covariance for net IGT Decision Making as a Function of Group using IQ, Working Memory, Interference Control, and Response Inhibition as Covariates (n= 77)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>eta2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrices TR</td>
<td>1</td>
<td>9167.22</td>
<td>13.52</td>
<td>.000</td>
<td>.160</td>
</tr>
<tr>
<td>Digits Total</td>
<td>1</td>
<td>56.04</td>
<td>.08</td>
<td>.775</td>
<td>.001</td>
</tr>
<tr>
<td>Stroop Interference</td>
<td>1</td>
<td>628.04</td>
<td>.93</td>
<td>.339</td>
<td>.013</td>
</tr>
<tr>
<td>SSRT</td>
<td>1</td>
<td>6065.12</td>
<td>8.95</td>
<td>.004</td>
<td>.112</td>
</tr>
<tr>
<td>BPD vs. Controls</td>
<td>1</td>
<td>8629.65</td>
<td>12.73</td>
<td>.001</td>
<td>.152</td>
</tr>
<tr>
<td>Error</td>
<td>71</td>
<td>677.83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Matrices Tr = IQ transformed, Stroop Interference = ratio (cw/c), SSRT = response inhibition
Levine’s test of significance= .427
R² = .390 (adjusted r²=.347)

Selection of Predictors for Primary Multiple Regression Analyses

The primary analyses in both studies consisted of correlational and standard multiple and logistic regression analyses. The predictors of net IGT performance were entered simultaneously, as this form of entry is considered suitable for exploratory purposes (Norman & Streiner, 2000). In order to accommodate an adequate case-to-variable ratio that avoided a type II error, fewer predictors were needed to determine the models of best fit. As a result of the strong collinearity among BDI and BAI scores (r =.80, n = 82, p = .000) and among BDI and ADSA scores (r =.71, n = 82, p = .000) and the stronger relationships of BDI to both dependent variables, BDI was considered the primary clinical variable of interest. As IQ and education were moderately correlated and because IQ was more strongly associated with IGT performance, education was entered as an initial predictor of decision making (Table 3.10), but it was deleted from the final model. In the presence or absence of IQ (in combination with EF) in a preliminary regression analyses, education did not contribute significantly to IGT performance (Table 3.10). Despite the weak correlations among some EF and the dependent variables, the predictor variables remained in the regression models as guided by the study hypotheses.

Reading ability was excluded as a predictor because it was unrelated to the primary study hypotheses and it was weakly associated with net IGT performance (r = .11) and suicide risk (r =
Given that IQ was theoretically relevant and strongly associated with net IGT performance in the BPD group, it was retained as a predictor. Because IQ was neither theoretically nor statistically relevant to suicide risk, it was deleted as a predictor. The difficult interpretation of the transformed variables was facilitated by examining the preliminary results using untransformed data.

In summary, the final predictors selected for the primary multiple regression analyses were based on the (1) strength of the correlations with the dependent variables, (2) the study hypotheses, and (3) the multicollinearity among predictors. Poor collinearity tolerance among BPD and BDI on net IGT performance was present (Table 3.11). Five independent variables, including group (BPD vs. HC), Stroop, IQ, SSRT, and Digit Span, with depression deleted, remained in the final model predicting IGT performance. Only four variables were selected to predict suicide risk (n = 39) to accommodate the smaller number of BPD subjects. These predictor variables included depression, Stroop interference, net IGT, and SSRT. Given that working memory demonstrated the weakest association with suicide risk (r = .02), it was deleted as a predictor. Standardized residual plot analyses of the final regression models were checked and met normally distributed assumptions. Casewise diagnostic checks involving Cook’s and Mahalonobis distances confirmed that no subjects were exerting undue influence on the results of the primary regression models.
Table 3.10
Preliminary Simultaneous Regression Analyses of net IGT Performance in Women with BPD and Healthy Controls controlling for depression and education (N = 75)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>CI of β</th>
<th>Tolerance.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD vs. HC</td>
<td>19.37</td>
<td>8.51</td>
<td>.30*</td>
<td>2.40</td>
<td>36.34</td>
</tr>
<tr>
<td>BDI</td>
<td>-.08</td>
<td>.30</td>
<td>-.04</td>
<td>-.66</td>
<td>.50</td>
</tr>
<tr>
<td>IQ (Transformed)</td>
<td>-.39</td>
<td>11.64</td>
<td>-.38**</td>
<td>-62.75</td>
<td>-16.30</td>
</tr>
<tr>
<td>Stroop Interference</td>
<td>-5.52</td>
<td>5.72</td>
<td>-.10</td>
<td>-16.93</td>
<td>5.89</td>
</tr>
<tr>
<td>Digit Span Total</td>
<td>.18</td>
<td>.83</td>
<td>.02</td>
<td>-1.47</td>
<td>1.83</td>
</tr>
<tr>
<td>SSRT</td>
<td>.12</td>
<td>.04</td>
<td>.28**</td>
<td>.04</td>
<td>.20</td>
</tr>
<tr>
<td>Education</td>
<td>1.02</td>
<td>1.10</td>
<td>.10</td>
<td>-1.18</td>
<td>3.22</td>
</tr>
</tbody>
</table>

* p = <.05; **; p < .01; *** p < .001

\[ R^2 = .409 \]
\[ Adj \ R^2 = .348 \]
\[ F(7,68) = 6.71, p = .000 \]

**Strengthening the Validity of the Findings.** The following steps were taken to strengthen the validity of the findings. Standardized measures of EF task performance were utilized. Screening for the presence or absence of BPD symptoms occurred within two weeks of testing, and BPD severity was assessed on the day of testing. Statistical assumptions assessing the normality, linearity, and homoscedasticity of data were checked and met, as required for ANCOVA and multiple regression analysis. The parallelism of regression slopes was ensured among groups. Two independent variables were successfully transformed to meet normal distribution requirements. An appropriate case-to-variable ratio was maintained for the analyses using the total sample, and it almost met regression requirements for the BPD sample (N = 39); hence, this analyses was exploratory and requires replication. Data analyses were initially conducted with and without two multivariate outliers, resulting in no differences in the findings; therefore, all subjects with complete data were included in the final analyses. (Six subjects had missing data.) The effect of depression on all EF performance was assessed. Collinearity tolerance among all the predictors in the regression models was checked. Unacceptable collinearity between BPD and depression resulted in the deletion of depression from the final model of IGT performance. Separate regression analyses of net IGT performance for each group.
were performed to ensure the consistency of findings as evident in the total sample. As depicted in Table 3.11, the same predictors remained significant for IGT decision making in women with BPD; however, the adjusted variance increased to 39%. Motor inhibitory control was the only significant predictor ($\beta = .45$, $p = 0.01$) of IGT performance in the control group with the same variables entered; however, the overall model was not significant ($F(4, 32) = 2.23$, $p = 0.09$). When working memory was deleted with three predictors remaining (IQ, Stroop and SSRT) to explain IGT performance in the control group, the regression model became significant ($p = .05$), with SSRT remaining as the sole significant predictor.

Table 3.11
Preliminary Simultaneous Regression Analysis of EF and IQ on the Prediction of IGT Performance in Women with BPD ($N = 39$).

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>SE</th>
<th>$\beta$</th>
<th>95% CI of $\beta$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrices $^a$</td>
<td>-60.02</td>
<td>14.53</td>
<td>-.66***</td>
<td>-.89.52</td>
<td>-.30.53</td>
</tr>
<tr>
<td>SSRT</td>
<td>.09</td>
<td>.04</td>
<td>.27*</td>
<td>.00</td>
<td>.17</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.55</td>
<td>1.13</td>
<td>-.07</td>
<td>-2.83</td>
<td>1.74</td>
</tr>
<tr>
<td>Stroop Int.</td>
<td>-2.88</td>
<td>6.73</td>
<td>-.06</td>
<td>-16.55</td>
<td>10.79</td>
</tr>
<tr>
<td>Constant</td>
<td>50.85</td>
<td>31.94</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$ = inverse transformation

$R^2 = .456$; adj $R^2 = .394$,

$F(4,35) = 7.35$, $p = .000$
Chapter 4: Affective Decision Making and Executive Function in Women with Borderline Personality Disorder (Manuscript 1)

Introduction

The ability to make decisions under uncertain conditions is arguably one of the most complex functions of the human brain (Cohen et al., 2005). Current evidence identifies the ventromedial regions as being critically involved in the evaluation and selection of uncertain choices (Bechara et al., 1994). Damage to these regions results in marked learning impairments needed to avoid long-term losses and difficulties in adapting behaviour relative to unanticipated outcomes.

Decision making is a complex executive function that requires attention to multiple sources of information about the consequences of an action and the probabilities of expected outcomes. Many individuals with Borderline Personality Disorder (BPD) manifest poor decisions in their personal and social relationships and do not appear to readily benefit from their prior experiences. These clinical observations are consistent with the characterization of BPD as a “stable state of instability” (Kernberg, 1986) involving intense emotional and behavioural dysregulation that may represent a degree of frontal limbic dysfunction (Soloff et al., 2003; de la Fuenta et al., 1997; Juengling et al., 2003; Berlin et al., 2005; Nigg et al., 2005). The emotional and behavioural dysregulation of the disorder is consistent with a range of executive function deficits reported in our review of 29 studies of cognitive function in BPD (LeGris & van Reekum, 2006). In particular, deficits involving decision making and inhibitory control were most consistently found across samples (LeGris & van Reekum, 2006). Nonetheless, very few studies have examined the relationships existing among inhibitory control mechanisms and decision making. Moreover, only one published study of “hot” decision making in BPD was located (Haaland & Landro, 2007). Given that the roles of unemotional or “cool” EF on affective or “hot” decision making continue to be debated (Bechara et al., 1994; Maia & McClelland, 2004; Fellows & Farah, 2005) and because no prior study has examined these particular executive functions in BPD, this investigation compares hot and cool executive function performance in adult women with BPD and healthy controls to examine their inter-relationships.

The neuropsychological literature of neurologic and psychiatric disorders in general has been supported by an increase in the use of neuro-imaging data, which suggests that
dysfunctional neural circuits of the prefrontal cortex play crucial roles in the emotional and behavioural regulation of higher order goal-directed behaviour known as executive function (Stuss & Knight, 2002). Executive functions include the abilities to plan, to judge, to consider and weigh options, to make complex decisions, to accurately perceive one’s abilities, to reorganize, and to implement and control or inhibit other thoughts or behaviours. These processes rely in large part on the integrity of the prefrontal cortex (PFC) and the interactions of the PFC with other brain regions (Stuss & Benson, 1986), such that the cognitive deficits observed in BPD may be associated with dysfunctions of the PFC. Despite the complex neurocircuitry of the PFC, the dorsolateral prefrontal cortex (DLPFC), anterior cingulate (ACC), and the orbitofrontal cortex (OFC/VMPFC) are three domains that are proposed to regulate working memory, inhibitory control, interference control, and complex decision making. These specific executive functions are compromised in many individuals with BPD (Ruocco, 2005; LeGris & van Reekum, 2006). Whether these executive control deficits precede the disorder or are the result of the disorder or its treatment are questions that remain, and they will require prospective, longitudinal study. However, laboratory assessments of cognitive function may provide important avenues for enhancing an understanding and treatment of the underlying deficits associated with BPD, which may go unrecognized and compromise treatment response.

**Background**

As proposed by Ernst and Paulus (2005), decision making involves three primary cognitive components: (1) the formation and valuing of a preferred choice, (2) the selection and execution of an action (requiring inhibition of competing interests, correction of errors, or the planned timing of one’s actions), and (3) an evaluation of the outcome of that choice. This final stage requires learning the differences between the expected value and the actual value of a selected option. The ability to balance or regulate these competing push/pull motivations in everyday life will guide effective action. In addition to a purely cognitive or rational analysis of decisional options, emotions also provide important input or motivational signals for adaptive decision making. These emotional signals are believed to depend on the integrity of the amygdala to be accessed through the ventromedial prefrontal cortex (Bechara et al., 1994, 2004). Irregularities in these specific limbic regions are reported to be affected in BPD (Tebartz van Elst et al., 2003; Silbersweig et al., 2007) and may be associated with these patients’ impaired decision making. Decisional impairment, as assessed by a variety of experimental laboratory
measures, has been consistently reported in all of the, admittedly few, studies of BPD (Dougherty et al., 1999; Bazanis et al., 2002; Dowson et al., 2004; Kirkpatrick et al., 2007; Haaland & Landro, 2007).

The Iowa Gambling Task (IGT) is a well-recognized emotional decision probe that mimics the uncertainty of real life where the rewards and penalties of a choice are uncertain (Bechara et al., 1994). Given the scarcity of probes that tap emotional related processes amid the longstanding evidence of emotional dysregulation as a core deficit of BPD (Linehan, 1993), it was surprising that no prior study of IGT performance in BPD was available at the time the present study was undertaken. Damasio’s (1994) Somatic Marker Hypothesis (SMH) has indirectly guided the interpretation of deficient IGT performance in many psychiatric samples (Dunn et al., 2006). This hypothesis proposes that deficits in emotional signalling (somatic states) result in poor social and personal judgements. Emotions are believed to facilitate the reasoning process at the time of deliberation, rather than as a consequence of the decision, which then improves one’s overall decisional ability (Bechara et al, 2002b). Specifically, the recall of a prior event and the emotion with which it was previously associated is stored in the ventromedial brain region and positively influences decision making. SMH was derived from the study of ventromedial lesioned patients who failed to generate somatic markers in anticipation of the risky IGT card selections. Normal subjects who generated these anticipatory markers decided advantageously and avoided the risky decks. Bechara et al. (1994, 2000a) concluded that the lack of anticipatory autonomic SCR activity in lesioned patients impaired their ability to foresee the future consequences of their decisions, also known as a “myopia of the future” or an insensitivity to future consequences, whether positive or negative.

Behavioural impulsivity is also strongly linked to BPD (van Reekum et al., 1996; Links et al., 1999; Berlin & Rolls, 2004) and may be the result of a variety of inhibitory control deficits that underlie impulsive behaviour. Weak associations among impulsive traits and disinhibitory tasks may stem from the poorly conceptualized distinctions among inhibitory processes (Nigg, 2000). For example, Nigg (2000) categorizes Stroop interference performance as a type of cognitive control involving the deliberate suppression of automatic, distracting, or interfering thoughts. This type of inhibitory control is frequently reported as impaired in BPD (Swirskey-Sacchetti et al., 2003; Besteiro-Gonzalez et al., 2004; Dougherty et al., 1999; Monarch et al., 2004; Kunert et al., 2003). Other tasks, such as the Stop and Go/No Go are known also to recruit
the motor dimensions of inhibitory control. However, little understanding of the unique control
deficits that may influence affective decision making currently exist. Impairments in reverse
learning or selective attention may represent general inhibitory deficits affecting decision
making, as observed in many adults with impulsive reward-seeking behaviour involving
substance misuse (Grant et al., 2000), pathological gambling (Cavedini et al., 2002), and eating
disorders (Cavedini et al., 2004). These clinical disorders are frequently co-morbid with BPD.

One interesting observation of the ventromedial patients studied by Bechara et al. (1994)
was that they demonstrated poor performance on the IGT, but they displayed average
intelligence and intact cool executive functions, suggesting that IGT performance may be
independent of other EFs. Bechara et al. (1998) described the relationship of working memory
and IGT performance in ventromedial patients as asymmetric in that decisional impairment could
exist in the presence of normal working memory, but impaired working memory seemed to
somatic markers as representing reward-punishment experiences rather than future-oriented goal-
directed decision making. Others argue that poor IGT performance is a consequence of impaired
reverse learning (Fellows & Farah 2005), increased working memory load (Hinson et al., 2002;
Clark & Manes, 2004), and poor inhibitory control (Noel et al., 2007), thus challenging the SMH
as the sole source of deficient IGT performance. Whether IGT decision making is independent
of intellect, working memory, and inhibitory control in clinical and healthy control samples
continues to be debated amid recent suggestions that IQ and EF may also be separable from IGT
performance (Toplak et al., 2010). Thus, IGT performance remains complex and may rely on
shared resources involving both focal (ventromedial prefrontal) and more generalized
(dorsolateral prefrontal) brain regions (Levine et al., 2005).

The primary purposes of the present study are (1) to compare affective or hot IGT
decision making and other cool executive function performance in a sample of outpatient women
with BPD and in healthy controls, (2) to examine the extent to which IGT decision making is
associated with working memory, response inhibition, interference control, and IQ, and (3) to
identify the executive functions that best predict BPD status. Because IQ is inconsistently
impaired in BPD (LeGris & van Reekum, 2006) yet believed by some to affect IGT performance
(Monterosso et al., 2001; Ernst et al., 2003a; Haaland & Landro, 2007), the relationships among
IQ and executive functions were also examined. We anticipate that (1) women with BPD would
make more disadvantageous choices on the IGT than would healthy controls, (2) IGT performance would be independent of other EF performance as supported by the Somatic Marker Hypothesis, and (3) poor affective decision making would be a significant predictor of BPD status in keeping with the emotional dysregulation of the disorder.

Methods

This study included 83 female participants between 18 and 51 years of age; 42 had a confirmed diagnosis of BPD and the remaining 41 were free from any mental health or other medical problems. Given that more women than men are believed to suffer from the disorder, and gender is known to affect EF performance (Reavis & Overman, 2004; Bolla et al., 2004), this study targeted outpatient women with BPD who lived in the community and attended regular follow-up care. BPD participants were recruited from a recently completed treatment effectiveness trial for BPD (McMain et al., 2009) at two university teaching hospitals in a metropolitan city in Canada. Healthy female controls were acquired through formal and informal advertising targeting hospital staff and undergraduate health science students. Study eligibility was initially determined by a standardized telephone screening. Committees of both university-affiliated hospitals granted ethics approval.

Participants

BPD participants entered the present study with a confirmed diagnosis of Borderline Personality Disorder (4th ed., DSM-IV, American Psychiatric Association, 1994) as assessed by SCID I (Spitzer et al., 1995) and IPDE interviews (Loranger, 1995) conducted by trained and blinded PhD clinicians and a certified psychiatrist. Full diagnostic protocols are described in McMain et al. (2009).

The current study required BPD participants to achieve a minimum of 6/10 on the McLean Screening Instrument for BPD (Zanarini et al., 2003), indicating active BPD status. To avoid medication withdrawal, BPD participants were eligible if they were stabilized on current prescribed medications; that is, they had experienced no severe side effects or change to their pharmacologic treatment for four weeks prior to testing. In addition to the ethical concerns of treatment withdrawal in research protocols, medicated BPD participants were considered more representative of the disorder. All participants were English-speaking and physically healthy. Excluded from the study were those patients with a known diagnosis of schizophrenia, bipolar
disorder, major psychosis, or known neurological disease or head injury involving any loss of consciousness. Participants with BPD were ineligible if diagnosed or treated for substance dependence/abuse within four months of testing or if they were presently suffering from clinical depression. Control subjects scoring > 2/10 on the McLean screen were also ineligible and were subject to the same exclusionary criteria as the BPD subjects.

General cognitive ability was measured using the Standardized Raven’s Matrices (Raven, 2003), which provided an estimate of fluid intelligence involving problem solving and perceptual reasoning. Clinical Measures included the 21-item Beck Anxiety Inventory (Beck et al., 1988) and the Beck Depression Inventory II (Beck. et al., 1996) because affective states may interfere with cognitive task performance. Higher scores represent greater severity. The 54-item Attention Deficit Scale for Adults (ADSA) (Trioli & Murphy, 1986) assessed symptoms related to Attention Deficit Disorder, where one of five categories for each item (never, seldom, sometimes, often, or always) was endorsed. Total ADSA Scores were utilized, with a score of 181 or more representing moderate to severe ADHD (Triolo & Murphy, 1986). Attention deficits may interfere with EF and other cognitive task performance. ADHD is an important co-morbid condition and may even increase the risk of BPD in adult women (Davids & Gaspar, 2007). The McLean Screening Instrument for BPD (Zanarini et al., 2003) assessed current BPD criteria. One item assessed eight of nine DSM-IV criteria with two items assessing the ninth criteria. Scores ranged from 0 to 10. A score of 7 or more indicated high sensitivity (.81) and specificity (.85) for BPD, which improved with subjects aged 30 or younger (sensitivity .87 and specificity .90).

Procedures

Standardized measures were administered individually and in identical order during a single three-hour session. A clinician/PhD trainee administered measures to 76 of the 83 subjects, and a trained RA administered measures to seven controls. Cognitive tasks preceded all behavioural measures. Depression and anxiety screens were completed by all participants. Current treatment status and known Axis I and II co-morbidity in BPD was acquired through structured interviews. Participants with BPD had completed or were nearing completion of their involvement in the RCT and were active in follow-up care; they completed all measures without obvious distress. Participants received a complete written description of the study, provided written consent, and received a nominal fee for the completion of all measures.
Measures

**Decision Making.** The IOWA Gambling Task (IGT) (Bechara et al., 1994, 2001) represents an ability to delay immediate reward in favour of longer term gain and requires self-monitoring and learning from prior experience. The computerized version of the IGT (Bechara et al., 2001) was used in this study. This version involved four card decks (A, B, C, and D) that appeared face down on the computer monitor. Participants selected as frequently as they wished from any deck to maximize a profit on a $2,000 loan of play money. Decks A and B were disadvantageous decks and selections from these decks would result in an overall net loss. Deck C and D were advantageous decks, and selections from these decks would result in an overall net gain. Participants were uninformed of how many deck selections would occur, but they were warned that some decks were worse than others were, and they were instructed to avoid the worst decks. Selections were tracked by a green bar at the top of the screen that depicted the cumulative wins and losses. Wins were accompanied by a happy face and a loud tone, whereas a frown with a quieter tone accompanied the punishing card selections. The main dependent variable was the total advantageous card selections minus the disadvantageous card selections \((C + D) - (A + B)\) on 100 trials which represented net decision-making performance. Intermediate decision scores were also calculated for each of five blocks of 20 cards to assess learning on the task. Higher scores represented more advantageous decisions.

**Executive Function Measures.**

**Working Memory.** Working memory, primarily under the control of the DLPFC, (Goldman-Rakic, 1993), represents the storage and manipulation of information in short-term memory, and it is critical for the regulation of future behaviour (Baddeley, 1997). The number of digits accurately repeated in forward (storage) and backward (manipulation) conditions on the Digit Span subtest of the WAIS-III (Weschler, 1997) assessed verbal working memory. On both tasks, the examiner read aloud a series of number sequences of increasing difficulty. Each sequence consisted of two trials with the same number of digits. Two points were awarded for correct responses on both trials. One point was awarded for one correct trial, and zero points were given if both trials were incorrect, which resulted in the discontinuation of the test. Maximum scores were 16 for forward recall and 14 for backward recall, totalling 30 points; total scores were used in this study.
**Inhibitory Control Tasks.** Two measures of executive inhibition assessed the participant’s ability to intentionally withhold or suppress attention or response to competing stimuli in order to achieve higher order goals (Nigg, 2000). One measure specifically assessed behavioural inhibition of a prepotent response (Stop Task), and the other was a measure of interference control (Victoria Stroop). Stroop interference tests the ability to selectively attend to conflicting tasks and control interfering information (Henik & Salo, 2004). The Victoria Stroop task (Regard, 1981; Sherman & Strauss, 2006) involved three reaction time conditions: colour naming, word reading, and interference. Each condition was depicted on separate pages of 24 coloured rectangles or words aligned in four columns and six rows. Participants were instructed to read the colours or words quickly without making errors. Interference control, the variable of interest measured in seconds, is typically calculated as the difference in the time for identifying colours from the time to name the ink of incongruent colour words. For example, the word green is printed in blue, and one must repress the automatic urge to say green. Ratio interference scores are recommended if cognitive slowing is suspected on baseline Stroop conditions (Troyer et al., 2006); they were used in this analysis. The Stroop task activates the anterior cingulate cortex (ACC) and the DLPFC, and it is considered important for self-regulation (Stuss et al., 2001).

Behavioural or motor inhibition was estimated by the computerized Stop Signal Task (Logan, 1994). Participants pressed designated left or right mouse keys when go signals, represented by an X or an O, appeared on the monitor, and they inhibited this response when an auditory warning sounded, which occurred randomly on 25% of the trials. The auditory tone sounded at variable delays (Stop Signal Delay or SSD), following the appearance of the go signal. A pre-programmed timing of the tone was increased or decreased by 50 milliseconds to ensure success on 50% of the stop trials. Because stopping cannot be observed, the difference between the time to execute the go and the titrated SSD provided an estimate of the Stop Signal Reaction Time (SSRT), the primary variable of inhibitory control. Five blocks of 48 trials were administered following a practice trial. Data on the final four blocks comprising 192 trials were analyzed. Because initial SSD started at 250 ms. and may have been far from the SSD values after titration, the first 48 trials were discarded. Longer SSRT represents weaker inhibition (Williams et al., 1999). Stop/go tasks are believed to represent dorsolateral/prefrontal cortex...
(Logan, 1994), but they have also been implicated in orbitofrontal functions (Horn et al., 2003; Dowson et al., 2004; Rogers et al., 1999).

**Statistical Analyses.** Raw scores were used for all of the analyses using the Statistical Package for the Social Sciences 13 for Windows (SPSS, Chicago). Pearson Correlation Coefficients were used to examine the relationships among each EF and net IGT performance. Group differences were assessed by t-tests, analysis of variance, and multiple and logistic regression analyses. Results were based on the uncorrected data sets and a near full sample size, with the exception of four control subjects for whom complete data on the STOP task was unavailable as a result of technical computer error. IGT data on one BPD subject was missing due to computer error. One control subject did not complete BDI and BAI screens for unspecified reasons. Net IGT performance, the primary dependent variable, was normally distributed with no outliers or extreme scores. The IQ distribution for the total sample was negatively skewed with three outliers requiring an inverse transformation that normalized the distribution. All assumptions relevant to the primary outcome analyses were checked and met.

**Results**

**BPD Sample Description**

Eighty-five percent of BPD women endorsed histories of Axis I co-morbidities, ranging from one (n = 6) to four disorders (n =4). The majority experienced two co-morbidities, most frequently involving anxiety disorders. Seventy-one percent of women with BPD suffered from prior clinical depression, 24% endorsed dysthymia with and without depression, and 29% suffered from eating disorders. Known co-morbid personality disorders involved dependent (n =3), avoidant (n =3), schizotypal (n =1), passive aggressive (n = 2), antisocial (n = 2), and paranoid (n =1). Few reported any problems with ADHD. Three BPD participants suspected childhood ADHD, but they were never diagnosed. Only one BPD subject endorsed a diagnosis of childhood ADHD. No participant reported any learning disability. Fifty percent of the BPD sample (n = 21) experienced a history of substance dependence/abuse involving alcohol, alcohol and stimulants, stimulants alone, cannabis, or prescription drugs.

Seventy-six percent of the BPD participants were stabilized on prescribed psychotropics (Table 4.1). Both groups were similar in age and were of Canadian-born status, but they differed significantly on years of education. Seventy-one percent of BPD participants endorsed low to
moderate anxiety. Thirty-two percent of BPD participants experienced normal to mild depression. Attention deficit symptoms differed significantly among groups, but the mean scores of the BPD group were shy of the 181 cut off representing moderate to severe ADHD (Trioli & Murphy, 1986); nonetheless, 43% of BPD participants had individual ADSA scores exceeding this cut.

Intelligence estimates were higher among the control group, but both groups performed within the normal range for their age (Spreen & Strauss, 1998). Group differences in Standardized Raven’s Matrices performance fell short of statistical significance (p = 0.08).
Table 4.1
*Demographic and Clinical Characteristics of Women with BPD and Healthy Controls*

<table>
<thead>
<tr>
<th>Demographics</th>
<th>BPD</th>
<th>Healthy Controls</th>
<th>statistic</th>
<th>p</th>
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<tbody>
<tr>
<td><strong>Demographics</strong></td>
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<tr>
<td>Age (Mean (SD))</td>
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<td>31.2 (9.0)</td>
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<td>.644</td>
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<td>Education (yrs) (Mean (SD))</td>
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<td>23</td>
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<tr>
<td>Married/CL</td>
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<td>14</td>
<td></td>
<td></td>
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<tr>
<td>Sep/divorced</td>
<td>5</td>
<td>4</td>
<td>χ²</td>
<td>.297</td>
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<td>Employment</td>
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<td></td>
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<tr>
<td>Employed/Student Full time</td>
<td>15</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employed/student part time</td>
<td>8</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed/seeking</td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed/not seeking</td>
<td>13</td>
<td>0</td>
<td>χ²</td>
<td>.000</td>
</tr>
<tr>
<td>Accommodation</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Lives alone</td>
<td>14</td>
<td>4</td>
<td>χ²</td>
<td>.009</td>
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<tr>
<td>Lives with others</td>
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<td>37</td>
<td></td>
<td></td>
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<tr>
<td>Canadian Born</td>
<td>35</td>
<td>33</td>
<td>χ²</td>
<td>.920</td>
</tr>
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<td><strong>Clinical Measures:</strong></td>
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<tr>
<td>BDI (63) (Mean (SD))</td>
<td>25.0 (13.9)</td>
<td>4.3 (4.8)</td>
<td>t</td>
<td>.000</td>
</tr>
<tr>
<td>BAI (63) (Mean (SD))</td>
<td>24.0 (14.6)</td>
<td>6.5 (6.3)</td>
<td>t</td>
<td>.000</td>
</tr>
<tr>
<td>ADSA (270) (Mean (SD))</td>
<td>177.8 (20.1)</td>
<td>135.3 (20.3)</td>
<td>t</td>
<td>.000</td>
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</tbody>
</table>

**IGT Performance**

A score of 10 or more on the IGT indicated normal performance in ventromedial lesioned patients (Bechara et al., 2001, 2007). Sixty-three percent (26/41) of the BPD sample had net decision scores of less than 10. These numbers were reversed in the control group, where 63%
performed normally on the IGT. Significant group differences were present on three of the four card decks (B, C, and D), supporting the use of the net IGT score as the primary dependent variable. Large group differences in net decision making were evident (Cohen’s $d = 0.72$). In support of our initial hypothesis, participants with BPD selected more frequently from the disadvantageous decks and made fewer advantageous card selections than did the controls. There were no significant differences among groups on the mean number of card selections from decks that varied by high or low frequency of punishment (that is, Decks A and C versus Decks B and D).

No significant differences in IGT performance were found among BPD participants with (M = -2.50, SD = 6.6) or without a prior history of substance abuse (M = .33, SD = 7.0, $p = .77$). The role of psychotropic medication on cognitive task performance remains controversial, and to address whether psychotropic medications may have affected IGT performance, a one-way ANOVA was conducted. As depicted in Table 1, all participants with BPD were divided into five groups (0 = no medications to four classes of medications). No significant differences in IGT performance were evident among unmedicated participants and those on any combination of psychotropics, $[F(4,36) = 1.25, p = .31]$. A two-way between group analysis of variance examined the effects of substance abuse history and current psychotropic effects (0-4) on net IGT performance. There were no significant main effects for any class of medication $[F(4,31) = 1.31, p = .29]$ nor history of substance abuse $[F(1,31) = .67, p = .42]$ on net IGT performance and no significant interaction effects $[F(4,31) = .82, p = .53]$. Despite the lack of statistical significance in IGT performance among medicated and unmedicated women with BPD, trends in their IGT performance were examined for potential clinical relevance, as depicted in Figure 4.1. It is understood that these “non-significant” trends of IGT performance require confirmation in more equivalent sized groups of medicated and non-medicated BPD samples; it remains unclear whether decisional performance is affected by medications, degree of pathology, or other potential confounds. Participants with BPD taking antidepressants only appeared to achieve normal IGT performance in contrast to those on no medications, or any other combination of medications, suggesting that antidepressants may improve IGT decision making in BPD women. Interestingly, mean IGT performance appeared to be noticeably improved when anticonvulsants were also added to other combinations of medications. Anticonvulsants and antidepressants are
typically prescribed to stabilize mood in BPD (APA. 2000), and they may reflect an improvement in emotional regulation, which positively affects IGT performance.

Figure 4.1
*Non-Significant Trends in Net IGT performance by Psychotropic Medications in Women with BPD*

![Graph showing the impact of different classes of psychotropic medications on Net IGT performance](image)

Note: one class = antidepressants only; two classes = antidepressants + antianxiety drugs; 3 classes = antidepressants + anti-anxieties + neuroleptics; 4 classes = antidepressants + anti-anxieties + neuroleptics + anticonvulsants.

To examine decision making over time, mean net IGT scores were calculated for each block of 20 cards (Figure 4.2). Blocks of intermediate decision making were normally distributed, except for Block 2 which required a degree of freedom adjustment. The ANOVA for repeated measures (group as the between subject factor and mean block decision making as the within subject factor) revealed a moderate main effect for block \[F(4,78) = 9.49, p < .001, r_{\text{effect size}} = .31\], indicating that decision making in both groups changed over time. A significant but small effect for group \[F(1,81) = 10.74, p = .002, r_{\text{effect size}} = .12\] indicated that comparison controls made relatively more advantageous and less disadvantageous deck selections across blocks compared to women with BPD. BPD women and controls differed significantly on Blocks 2 through 5 of the IGT, but differences were most pronounced at Block 3 \[F= 7.23, p = .009\] and Block 5 \[F=10.03, p=.002\]. Block 3 represents the hunch phase where knowledge of the good
and bad decks are clearer, but the probabilities of punishment remain uncertain (Bechara et al., 1994). Block 5 represents the conceptual phase when subjects typically have an explicit understanding of the successful decks. There was no significant interaction between group and any block of decision making \([F(4, 78) = 1.41, p = .238 \text{ effect size } .02]\). This finding suggests that the BPD group did learn to pick cards from the advantageous decks over time, but they selected them less frequently than did the control group, and they may have been slower to learn from their prior selections.

**Figure 4.2. Mean Advantageous versus Disadvantageous IGT Card Selection in women with (cases) and without (controls) Borderline Personality Disorder**

Bars represent SEM

**EF and IGT Performance**

Unadjusted group differences on executive function performance are depicted in Table 4.2. Despite significant differences in working memory, the mean scores of both groups fell within the age appropriate standardized norms of Digit Span performance (WAIS, 1997). BPD subjects also performed more slowly than controls did on all Stroop baseline and Stroop interference difference scores. Given that groups differed in years of education, education was
controlled in a series of ANCOVA analyses. Initial group differences in working memory ($F (3.79) = 1.25, p = 0.27$) and Stroop performance became non-significant when adjusted for education [Stroop colour; ($F [2.82] = 1.81, P = 0.18$); Stroop word ($F [2.82] = 1.84, P = 0.18$); incongruent colour/word, ($F [2.82] = 3.31, P = 0.07$); and interference difference ($F [3.79] = 2.33, P = 0.13$)]. Motor (SSRT) inhibition and Stroop ratio interference scores did not differ between groups with or without control for education. Group differences on IGT decision making remained significant with education ($F [2.79] = 6.92, P = 0.01$) and IQ and education controlled ($F [3.78] = 5.81, P = 0.02$). BPD women’s “cool” EF fell within a range of normal performance.
Table 4.2

Mean Differences in IGT Decision Making and other EFs in Women with BPD and Healthy Controls

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<thead>
<tr>
<th></th>
<th>BPD</th>
<th>Healthy Controls</th>
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<tbody>
<tr>
<td></td>
<td>Mean (SD) n</td>
<td>Mean (SD) n p</td>
</tr>
<tr>
<td>IGT (Total selections/100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck A (disadvantageous)</td>
<td>15.90 (6.5) 41</td>
<td>13.40 (5.2) 41 .058</td>
</tr>
<tr>
<td>Deck B (disadvantageous)</td>
<td>33.26 (14.7) 41</td>
<td>26.05 (12.3) 41 .018</td>
</tr>
<tr>
<td>Deck C (advantageous)</td>
<td>19.98 (8.0) 41</td>
<td>23.34 (13.4) 41 .029</td>
</tr>
<tr>
<td>Deck D (advantageous)</td>
<td>30.48 (14.7) 41</td>
<td>37.20 (14.5) 41 .040</td>
</tr>
<tr>
<td>Net Decision Making</td>
<td>-.71 (30.2) 41</td>
<td>21.07 (30.3) 41 .002</td>
</tr>
<tr>
<td>C+D Advantageous</td>
<td>48.45 (17.0) 41</td>
<td>60.54 (15.1) 41 .001</td>
</tr>
<tr>
<td>A+B Disadvantageous</td>
<td>49.17 (17.0) 41</td>
<td>39.46 (15.2) 41 .008</td>
</tr>
<tr>
<td>A+C (frequent)</td>
<td>33.88 (11.4) 41</td>
<td>36.76 (13.2) 41 .292</td>
</tr>
<tr>
<td>B+D (infrequent)</td>
<td>63.74 (14.3) 41</td>
<td>63.24 (13.2) 41 .870</td>
</tr>
<tr>
<td>Digit Span /WAIS III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digits Forward</td>
<td>10.23 (2.3) 41</td>
<td>11.00 (2.4) 41 .155</td>
</tr>
<tr>
<td>Digits Back</td>
<td>6.34 (2.1) 41</td>
<td>7.61 (2.4) 41 .020</td>
</tr>
<tr>
<td>Total Digits</td>
<td>16.54 (3.9) 41</td>
<td>18.56 (4.2) 41 .041</td>
</tr>
<tr>
<td>Stop Task (ms.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSRT</td>
<td>256.33 (93.6) 42</td>
<td>233.77 (55.1) 38 .199</td>
</tr>
<tr>
<td>GO RT</td>
<td>640.99 (172.2) 42</td>
<td>513.64 (140.7) 41 .737</td>
</tr>
<tr>
<td>GORT SD</td>
<td>136.73 (43.0) 42</td>
<td>122.66 (30.4) 41 .089</td>
</tr>
<tr>
<td>SSD</td>
<td>53.52 (9.89) 42</td>
<td>50.25 (7.58) 38 .103</td>
</tr>
<tr>
<td>Standard Progressive Matrices</td>
<td>46.80 (11.0) 41</td>
<td>50.44 (7.0) 41 .078</td>
</tr>
<tr>
<td>Victoria Stroop (sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Colour Naming</td>
<td>13.21 (4.5) 42</td>
<td>11.38 (2.2) 41 .022</td>
</tr>
<tr>
<td>ii) Word Reading</td>
<td>10.23 (3.7) 42</td>
<td>8.60 (1.6) 41 .021</td>
</tr>
<tr>
<td>iii) Colour word</td>
<td>26.78 (11.9) 42</td>
<td>21.17 (4.3) 41 .006</td>
</tr>
<tr>
<td>iv) Interference (iii-i)</td>
<td>13.57 (9.0) 42</td>
<td>9.77 (4.3) 41 .018</td>
</tr>
<tr>
<td>v) Interference (iii/i)</td>
<td>2.02 (.62) 42</td>
<td>1.91 (.47) 41 .342</td>
</tr>
</tbody>
</table>

Pearson product-moment correlations were conducted on the total sample and on each group separately (Table 4.3). Poor IGT performance was significantly associated with weaker interference control in the BPD group (r = -.33) and verged on significance in the total sample (r = -.22, p = 0.05). Working memory was not associated with IGT performance in either group.

Normal stopping reaction time (SSRT) was positively and significantly associated with improved...
decision making in the control group ($r = .36, p < 0.01$), but not in the BPD group ($r = .18$).

Higher intellect was strongly associated with improved decisions in BPD participants, but not in healthy control participants. Therefore, IQ and SSRT associations with net IGT performance varied according to group.

Table 4.3

*Pearson Product Moment Correlations of EF and IGT Decision Making*

<table>
<thead>
<tr>
<th>Executive Functions</th>
<th>HC+ BPD</th>
<th>BPD</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory Working Memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Span Forward</td>
<td>.19</td>
<td>.23</td>
<td>.06</td>
</tr>
<tr>
<td>Digit Span Back</td>
<td>.17</td>
<td>.15</td>
<td>.04</td>
</tr>
<tr>
<td>Digit Span Total</td>
<td>.20</td>
<td>.22</td>
<td>.05</td>
</tr>
<tr>
<td>Inhibitory Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSRT</td>
<td>.16</td>
<td>.19</td>
<td>.36*</td>
</tr>
<tr>
<td>IQ (Raven’s Matrices)</td>
<td>.44***</td>
<td>.59***</td>
<td>.12</td>
</tr>
<tr>
<td>Cognitive Interference:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Naming Colours</td>
<td>-.14</td>
<td>-.05</td>
<td>-.09</td>
</tr>
<tr>
<td>(ii) Naming Words</td>
<td>-.15</td>
<td>-.02</td>
<td>-.15</td>
</tr>
<tr>
<td>(iii) Naming ink of Colour Words</td>
<td>-.28*</td>
<td>-.24</td>
<td>-.11</td>
</tr>
<tr>
<td>(iv) Stroop Ratio Interference (iii/i)</td>
<td>-.22</td>
<td>-.33*</td>
<td>-.01</td>
</tr>
</tbody>
</table>

* $p$ is significant at the .05 level, ** $p < .001$

Stroop interference= Victoria Version, IQ = Standard Progressive Matrices; SSRT = Stop Signal Reaction Time on the Logan Stop Task

**Correlations among Clinical factors and EF Performance**

Relationships among the clinical measures and EF performance were examined using Pearson Product Moment correlations and Analyses of Covariance. McLean Screen for BPD was more strongly associated with IGT performance ($r = -.35, p < .01$) than with depression ($r = -.32, p < .01$) or anxiety ($r = -.32, p < .01$). Attention deficits scores were not significantly associated with any EF, including IGT performance. As BDI and BAI measures were highly correlated ($r = .80, p < .01$), a series of ANCOVAs determined whether depression or anxiety (covariates) demonstrated stronger main effects on each EF treated as the within subject factor and group (BPD vs. healthy controls) as the between subject factor. Depression main effects
were consistently stronger than were anxiety effects on all EF, including IGT performance. Similarly, when the depression and ADSA \((r = .71, p = .000)\) were entered as covariates on each EF, depression consistently exceeded ADSA effects, such that depression was considered the major clinical confound on EF performance. Of note, however, depression was highly associated with BPD (Mclean Screen; \(r = .72, p < .01\)), indicating considerable shared variance. Depression was significantly but weakly associated with working memory \((r = -.24, p < .05)\) and IQ \((r = -.22, p < .05)\). Depression, anxiety, ADSA performance, and years of substance abuse history were not significantly associated with net IGT performance in the BPD sample.

To examine the means of IGT performance between groups, an analysis of covariance was performed with the dependent variable net IGT performance, the grouping factor (BPD and healthy controls), and the covariates of working memory, IQ, interference control, and motor inhibition. A preliminary analysis established that the assumption of parallelism of regression was met. The ANCOVA was significant; BPD status showed significance at the .001 level. The unadjusted and adjusted means of IGT performance are depicted in Table 4.4.

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted</th>
<th></th>
<th></th>
<th>Adjusted</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N  M  SD</td>
<td>M  SE CI</td>
<td>N  M  SE</td>
<td>95% CI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPD</td>
<td>40 -1.73  30.42</td>
<td>-.52 4.19</td>
<td>-8.87 7.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H Controls</td>
<td>37 22.73  29.48</td>
<td>21.43 4.36</td>
<td>12.73 30.12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To understand the relative contributions of each EF to decision making, a standard multiple regression analyses was conducted (Table 4.5), which also included the primary clinical factors that may have influenced IGT performance. As depression and anxiety were equally associated with decision making \([r = -.32, n = 81, p = .004]\) and depression was highly correlated with BPD, depression and anxiety were deleted as clinical predictors in this model. Variables entered simultaneously in a single block were group (BPD versus HC), SSRT, working memory, Stroop interference, education, and IQ transformed. Collectively, these variables explained 35% of the adjusted variance in IGT decision making, a moderate effect according to Cohen (1988).
In order of importance, IQ, group (BPD versus HC), and intact motor inhibitory control (SSRT) were significant predictors of net IGT performance \[F (6,70) = 7.80, p = .000\]. Working memory, interference control, and education did not contribute significantly to IGT performance. When a regression analysis was repeated in the BPD sample \((n = 40)\), with depression, Stroop interference, IQ, and motor inhibition entered as predictors, the adjusted variance of net IGT DM increased to 39% \[F(4,35) = 7.26, p = .000\], explained primarily by IQ \((\beta = .63, p = .000)\) and motor inhibition \((\beta = .28, p = .03)\). Depression \((\beta = .03, p = .84)\) and Stroop interference \((\beta = .06, p = .65)\) did not significantly predict IGT performance in BPD subjects.

**Table 4.5**

*Simultaneous Multiple Regression of Predictors of Net IGT performance in Women with BPD and Healthy Controls (N = 77)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>(\beta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>-19.88</td>
<td>6.41</td>
<td>-32.65</td>
<td>-7.10</td>
<td>-.31**</td>
</tr>
<tr>
<td>IQ(^a)</td>
<td>-39.60</td>
<td>11.55</td>
<td>-62.64</td>
<td>-16.55</td>
<td>-.38**</td>
</tr>
<tr>
<td>Stroop cw/c</td>
<td>-5.15</td>
<td>5.67</td>
<td>-16.64</td>
<td>6.15</td>
<td>-.09</td>
</tr>
<tr>
<td>SSRT</td>
<td>.12</td>
<td>.04</td>
<td>.04</td>
<td>.19</td>
<td>.28**</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.14</td>
<td>.81</td>
<td>-.148</td>
<td>1.76</td>
<td>.02</td>
</tr>
<tr>
<td>Education</td>
<td>1.22</td>
<td>1.08</td>
<td>-.93</td>
<td>3.37</td>
<td>.12</td>
</tr>
<tr>
<td>Constant</td>
<td>19.76</td>
<td>30.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) = inverse transformation; **p < .01  
\(F (6.70) = 7.80, p = .000\), \(r^2 = .40\); adjusted \(r^2 = .35\)

**IQ and IGT Performance.** To clarify the relationship of IQ to decision making, raw matrices scores were dichotomized into categories of high (50-60) and low (30-49) performance. With outliers removed, 16 control and 17 BPD subjects were classified as low matrices performers. Twenty-five controls and 21 BPD subjects were classified as high matrices performers (Table 4.6). A two-way ANOVA (BPD and Controls x high/low matrices) produced a near significant but small interaction \([F (3,74) = 3.43, p = .06, \text{partial } \eta^2 = .04]\). The main effect for group \([F (3,74) = 10.54, p = .002]\) and the main effect for IQ \([F (3,74) = 5.73, p = .02]\) remained
significant. Although higher IQ was associated with improved IGT performance in both groups, healthy controls with lower IQ performed advantageously on the IGT, relative to BPD women with low matrices performance who performed poorly on the IGT. The decision making of healthy controls was not associated with IQ such that IQ does not appear to fully account for the differences in decision making among groups.

Table 4.6

<table>
<thead>
<tr>
<th>Net IGT</th>
<th>Lower Matrices</th>
<th>Higher Matrices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>BPD*</td>
<td>17</td>
<td>-13.8</td>
</tr>
<tr>
<td>Healthy Controls</td>
<td>16</td>
<td>19.5</td>
</tr>
</tbody>
</table>

Lower Raven’s Matrices (30-49), Higher Raven’s Matrices (50-60)
* p <.01
BPD with lower and higher Matrices significantly differed on IGT (t=-3.36, p = .002)
Mean IGT performance among controls with hi and low IQ did not significantly differ.
Group F (3,74) = 10.54, p = .002; IQ F (3,74) = 6.14, p = .016, grp X Hi/low IQ F (3,74) = 3.43, p = .066

To address the final hypothesis of which EF were most predictive of group status, a binary logistic regression involving the predictors of working memory, IQ, SSRT, Stroop interference, and net IGT was computed. These variables significantly predicted group status, \( \chi^2 = 17.86, \ df = 5, \ N = 77, \ p < .01 \); however, only IGT performance remained significant. Table 4.7 presents the odds ratios, which suggest that the likelihood of being classified with BPD is decreased for every unit increase in net IGT performance. This model correctly classified 73% of cases and 67% of controls.

Table 4.7

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Odds Ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digits Total</td>
<td>-.07</td>
<td>.07</td>
<td>.93</td>
<td>.314</td>
</tr>
<tr>
<td>Net IGT</td>
<td>-.03</td>
<td>.01</td>
<td>.97</td>
<td>.003</td>
</tr>
<tr>
<td>SSRT</td>
<td>.01</td>
<td>.00</td>
<td>1.01</td>
<td>.189</td>
</tr>
<tr>
<td>Raven Matrices</td>
<td>.03</td>
<td>.04</td>
<td>1.03</td>
<td>.498</td>
</tr>
<tr>
<td>Stroop Interference</td>
<td>.04</td>
<td>.05</td>
<td>1.04</td>
<td>.433</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.28</td>
<td>2.53</td>
<td>.28</td>
<td>.614</td>
</tr>
</tbody>
</table>

73% of BPD cases and 67% of controls were correctly classified. (\( \chi^2 = 17.86, \ df=5, \ n=77, \ p<.01 \).
Summary of Findings

Affective decision making in women with BPD and the executive functions that may influence IGT performance relative to controls were tested. In support of the first hypotheses, BPD women demonstrated disadvantageous decisions on the IGT compared to controls. Decisional impairment in BPD women was not explained by weaker, albeit normal, IQ, working memory, interference control, or motor inhibition, thus confirming the second hypothesis. Furthermore, decisional impairment did not appear to be due to differences in education, a history of substance abuse, current psychotropic use, or current levels of depression. IGT decision making was the only variable to distinguish BPD participants from controls, confirming the final study hypothesis. This is the sixth known study to consistently report decisional impairment in BPD. It is the first report of IGT impairment in an all-female outpatient BPD sample that is consistent with the assumptions of the SMH. IGT decision-making performance, believed to represent functions within the ventromedial cortical and amygdala regions, appears to be separable from the EFs related to the dorsolateral PFC regions in women with BPD. While higher intelligence and normal range motor control predicted advantageous IGT decision making in the total sample, these EFs may be unnecessary for advantageous IGT performance. BPD women with lower IQ and normal motor control demonstrated disadvantageous IGT decisions, whereas controls with lower IQ and intact motor inhibition performed advantageously on the IGT.

Discussion

IGT Performance

Outpatient women with BPD appeared to demonstrate a preference for the immediacy of higher risk reward selections despite the magnitude of punishments, and this trend continued over time (blocks) on the IGT. The vulnerability for higher immediate gains, irrespective of the magnitude of loss, combined with a possible avoidance of the more frequent punishment decks (fewer selections from Decks A and C during the last 50 card selections) (Figure 3.1) may represent the typical approach/avoidant conflict in BPD subjects. High harm avoidance on the IGT has been associated with anxiety and more stringent attention to losses (Yechiam et al.,
2005). While attention to the frequency of loss was apparent in women with BPD, as evident by their increased selections from Decks B and D, the magnitude of loss appeared to be ignored as evident by their increasing Deck B selections. Upon general questioning immediately following IGT completion, many BPD women exhibited little accurate recollection of the magnitude of loss in favour of a more accurate recollection of wins, possibly suggestive of a greater sensitivity to reward. A significant inverse association of Stroop interference control and IGT decision making in women with BPD may further implicate difficulties in inhibiting the previously rewarding deck selections, or it may represent problems in error monitoring or attending to all cues on the IGT. The apparent inability of BPD women to learn from their prior mistakes on the IGT (i.e., increasing their Deck B selections during the last 50 cards) may also reflect an inattention or insensitivity to the negative consequences of their behaviour. BPD women reverted to their poor decisions during the final phase of the IGT when an awareness of successful strategies normally becomes more explicit. Whether BPD women were unaware of or were slower to learn the successful IGT strategies cannot be confirmed in this preliminary analysis. A sensitivity to proximal or more immediate reward typical of IGT impairment can be likened to the frequently reported “aversion to delay” behaviour (Bazanis et al., 2002; Dougherty et al., 1999) and shortened future time perspective (Berlin & Rolls, 2004) previously observed in BPD subjects. The valuing of immediate and larger reward may overpower the consideration of more harmful future punishment in women with BPD. To confirm the specific nature of the IGT deficits in BPD and to explore the sensitivity to punishment hypothesis, the variant version of the IGT is warranted in future investigations where immediate punishments (followed by even greater rewards) replace the immediate reward selections of the traditional IGT used in the present study.

**EF and IGT Performance**

Working memory and baseline Stroop associations with IGT performance were weak in BPD subjects but even weaker in controls, reinforcing the notion of the separability of working memory and Stroop interference from IGT performance. The relationships of EF to IGT performance may be asymmetric as previously characterized by working memory and IGT decision making (Bechara et al., 1998). In other words, normal EF performance does not guarantee advantageous IGT decision making, but impaired working memory and Stroop performance may worsen IGT performance. Overall, advantageous IGT decision making was
explained by higher intellect, which protected some but not all women from poor card choices; BPD pathology that clearly compromises IGT performance and longer but normal stopping ability. Normal range stopping ability in both groups was the weakest predictor of IGT performance and was attributed primarily to the control group. Normal range stopping ability seems congruent with IGT mastery; however, this was not apparent in the BPD group, suggesting that other factors beyond motor control may have explained their disadvantageous choices. Healthy controls may have engaged in a proactive speed accuracy trade off where they waited for the stop signal to occur, thus increasing their SSRT. According to Leotti and Wagar (2009), a speed accuracy trade off on the STOP Task may reflect a decisional process rather than a pure motor inhibitory process, and as such it may explain the positive associations of SSRT and IGT performance in control participants. ADSA performance, considered to represent many aspects of behavioural impulsivity (Dowson et al., 2004), was not significant to the IGT performance of either group. The contributions of improved intellect and intact inhibitory control to decision making does not fully contradict the SMH given that pure executive processes alone or knowledge of a situation unassisted by emotion does not guarantee advantageous choices (Bechara et al., 2002b). The present findings support normal range executive control and impaired net IGT performance in BPD, as observed in other psychiatric populations (Bechara et al., 1998, 2000a, 2001; Cavedini et al., 2002; Tranel et al., 2002; Bechara & Martin, 2004; Cavedini et al., 2004).

As the only predictor of BPD status, IGT impairment highlights the important role of emotion in the decision-making processes of women with BPD, which may be consistent with the affective dysregulation of the disorder. While a lack of emotional signalling characterizes the IGT performance of ventromedial lesioned patients, the potential for heightened or dysregulated emotional processing typical of BPD appears to be equally disadvantageous to their IGT decisional performance. This hypothesis, however, requires confirmation with an assessment of somatic marker activation during IGT performance.

**Inhibitory Control and IGT.** All participants were able to inhibit their responses on approximately 54% of the stop trials, proving that the tracking algorithm worked. Normal range SSRT in all participants—indicative of less impulsivity—predicted better decisions in the control group but not in the BPD group. Longer SSRT and advantageous decisions in controls may have been the result of a strategic speed accuracy trade off, where participants who value
accuracy over speed will take longer to perform the task (Leotti & Wager 2009). Some participants may also view unsuccessful stopping as errors, therefore reactively altering their strategy following successful and unsuccessful stop signal trials to increase the probability of inhibition on the next trial (Verbuggen & Logan 2009). Indeed, 75% of controls had accuracy scores of 99-100% in contrast to 38% of cases, suggesting that controls were more strategic in ensuring the accuracy (correct go) of their responses. This is the second report of normal range stopping performance in BPD (Nigg et al., 2005) using the Stop Task. Deficits in motor inhibition may prevent the interruption of a “bad choice” in spite of knowing the choice is disadvantageous, or it could represent unplanned or poorly planned actions (Ernst & Paulus, 2005). Nonetheless, these hypotheses await validation in BPD participants with impaired motor inhibition. While not fully understood, behavioural disinhibition has been associated with poor late IGT performance in recently detoxified alcoholics (Noel et al., 2007). Bechara (2005) also emphasizes the importance of inhibitory control on IGT performance by describing the somatic markers as the body’s “emotional” automatic warning to stop. Similar to current findings in BPD, however, Goudriaan et al. (2005) found no association between Go/No-go performance and IGT decision making in stabilized detoxified alcoholics, pathological gamblers, patients with Tourette’s syndrome, or healthy controls, making conclusions about the role of motor control on IGT performance in both clinical and control samples far from certain. More recently, Kertzman et al. (2011) confirmed the absence of an association between impaired Go/No-go performance and disadvantageous IGT performance in an Israeli sample of pathological gamblers.

Stroop interference control, representing selective attention and interference from distraction or conflict (Henik & Salo 2004), was not predictive of IGT performance in either group. To accommodate the strong association of IQ and Stroop interference in BPD subjects, a partial correlation controlling for IQ resulted in a non-significant correlation between IGT and Stroop performance \((r = -0.13, p = 0.44)\). Women with BPD may have been compromised in learning from the differences between their initial expectations and the actual outcomes of their deck selections. These difficulties may implicate feedback processing deficits that are reliant on IQ or that may represent inattention to all the cues on the IGT. Present findings are complemented by a recent report in impulsive pathological gamblers (Kertzman et al., 2011) where no significant relationship between impaired Stroop interference and disadvantageous IGT performance was observed. Furthermore, no behavioural measures of impulsivity were related to
impaired IGT performance in pathological gamblers. No association between ADSA and IGT performance were present in the current sample. Together, these findings suggest that performance on these measures of disinhibition and behavioural impulsivity do not contribute to deficits in IGT performance.

**IQ and IGT performance.** As commonly cited (Friedman et al., 2006), IQ estimates were significantly associated with all EFs except motor inhibition in this sample. Identical IQ performance in our sample of BPD women mirrors the findings of Swirsky-Sacchetti et al. (2003) in less educated BPD women. Using the WAIS, Nigg et al. (2005) also reported lower but normal IQ in BPD that was not explained by their extensive Axis I or Axis II co-morbidity. The robust correlation of IQ and decision making ($r = .44$) in the present sample is identical to a Norwegian BPD sample (Haaland & Landro, 2007) using the WAIS-R (Weschler, 1997). These replications represent concurrent validity in four BPD samples using reliable estimates of intellect, and they add to the evidence of intelligence and IGT associations in other psychiatric samples (Barry & Petry, 2008; Monterosso et al., 2001; Ernst et al., 2003a; Jollant et al., 2005). Higher IQ performance may improve the discrimination of rewards and penalties and/or the speed of information processing, thus facilitating more timely and novel problem solving. Higher IQ may also compensate for other factors that contribute to poor decisions. As the capacity to learn and detect rules is a key mechanism underlying IGT performance, the relationship between fluid IQ and IGT performance seems logical. While higher intellect may buffer participants from poor decisions, controls with lower intellect performed advantageously on the IGT, suggesting that factors beyond IQ are associated with advantageous decisions. This finding is consistent with the evidence in other samples that explicit knowledge of IGT strategies alone does not guarantee advantageous IGT performance (Anderson et al., 2006).

**Clinical Factors and IGT Performance.** Consistent with former reports (Bazanis et al., 2002; Jollant et al., 2005; Ernst et al., 2003b), net IGT performance in BPD women was not differentiated by a history of substance abuse. Despite attempts to control for states of depression, anxiety, and ADHD-related impulsivity, these measures were inseparable from BPD. Bazanis et al. (2002) also found that depression did not adversely affect decision making beyond that explained by BPD. Nigg et al. (2005) concluded that weaker SSRT and IQ performance in their female BPD sample were not attributed to extensive Axis I and II co-morbidity. Other
researchers have also demonstrated that psychotropic medications did not influence the EF or decision making performance of their study samples (Kirkpatrick et al., 2007; Bazanis et al., 2001; Ernst et al., 2003; Jollant et al., 2005). Effects of medications on our BPD sample however remain speculative.

Present findings may offer some preliminary specificity for BPD relative to ADHD adults. Despite the clinical similarities and co-morbidity of these disorders, deficits in working memory and motor inhibition (Hervey et al., 2004; Nigg et al., 2002), mild response interference deficits (Hervey et al., 2004; Boonstra et al., 2005; Nigg et al., 2005), and variable IGT performance (Ernst et al., 2003; Malloy-Diniz et al., 2007) have characterized ADHD adults. These deficits differ from present findings in BPD. In clinically depressed subjects, normal IGT performance has also been reported (Dalgleish et al., 2003; Garon & Moore, 2006). For example, Smoski et al. (2008) found that clinically depressed adults demonstrated more risk-averse behaviour than did healthy controls, and they outperformed them on the IGT. However, no study has reported normal decision making in BPD, nor has the nature of decisional impairment of BPD subjects been previously described as risk-averse. Clinical comparisons with ADHD adults and depressed adults in future research designs may confirm the specificity of these findings for BPD. Administering the alternate version of the IGT and simpler decision tasks may help to clarify the specific decisional impairment(s) associated with a diagnosis of BPD.

Current findings are limited by the cross-sectional nature of the study design, the convenience sampling of volunteer participants, the lack of systematic assessment of other co-morbidities, and the use of single measures to assess cognitive and behavioural performance. Results may not generalize beyond outpatient women seeking or currently involved in treatment. Biological evidence suggests that women and men with BPD should continue to be studied separately, as the neurological underpinnings of cognitive function differ by gender (Bohus et al., 2006). Other environmental factors contributing to poor decision making, such as sexual abuse histories, social support, psychosocial function and employment status, among others, should also be assessed in larger samples of women with BPD.

Decision making is an important area of study in BPD. The measurement of somatic activity during IGT performance would clarify whether the ventromedial or amygdala regions were primarily affected in BPD and may result in more targeted treatments. Amygdala patients
typically experience an absence of all three types of SCRs (reward, punishment, and anticipatory), while ventromedial impairment is confined to the absence of anticipatory SCRs (Bechara et al., 2001). The simultaneous use of the variant IGT version may clarify the sensitivity to punishment hypothesis of impaired decision making among this population. Administering tasks that tap the speed of information processing, such as the Digit Symbol, and the use of decision tasks that are less reliant on IQ may further delineate the specific mechanisms underlying poor decision making. The influence of affect on decision making warrants more controlled study given that negative emotions have been linked to high punishment card selections (Gray & McNaughton, 2003). Moreover, assessments of clinically depressed controls may clarify the effects of mood on the EF performance of dysthymic women with BPD.

Impaired IGT decision making appears to be independent of other EF performance in women with BPD, offering partial, indirect support for the Somatic Marker Hypothesis. Decision making constitutes an important life skill that can be taught, learned, and re-mediated, and it warrants greater attention in clinical practice. Because impaired IGT decision making has been related to serotonin dysfunction (Mareux et al., 2009) and because serotonin deficiencies are associated with greater suicide risk (Mann, 2003), the relationships of IGT decision making and risk for suicide in BPD warrants further understanding. Decision making impairment may represent a cognitive vulnerability for the disorder.
Chapter 5: An Exploratory Investigation of Executive Function and Suicide Risk in Women with BPD (Manuscript 2)

Introduction

Ten percent of individuals with Borderline Personality Disorder (BPD) will die from suicide (Paris & Zweig-Frank, 2001), a rate 50 times greater than the general population. The intense behavioural and emotional dysregulation of the disorder implicates a degree of frontal lobe dysfunction (De la Fuenta et al., 1997; Soloff et al., 2003) that, if unrecognized, will compromise treatment response. Although a range of neuropsychological deficits, particularly those involving executive control functions, have been reported frequently in BPD (LeGris & van Reekum, 2006), little is known of the relationships among executive function deficits and suicide risk. Executive functions (EFs) are purposeful higher order complex processes of the prefrontal cortex (PFC) that regulate goal-oriented thought and behaviour. The thoughts, plans, and actions to end one’s life may represent a range of EF deficits; however, the sensitivity of unique EF to suicide risk in BPD has yet to be examined.

BPD is an important risk factor for both attempted and completed suicides (Runeson, 1989). Even with self-harm excluded, BPD is strongly associated with suicidal behaviour beyond that attributed to clinical depression, substance abuse, or other personality disorders (Brodsky et al., 1997; Yen et al., 2004). Longitudinal studies demonstrate that 50% of BPD individuals will experience at least one severe suicide attempt, and they will commit on average three lifetime attempts, making them therefore at chronic risk for suicide completion (Soloff et al., 1994). A history of suicide attempts is the strongest predictor of completed suicides, more so than any other diagnosis, and it increases the likelihood of future attempts four-fold (Oquendo et al., 2003). Because BPD is the only disorder in which suicidal behaviour is a diagnostic criterion, this population is highly relevant to our understanding of suicide risk, defined as any thought or behaviour involving a conscious intent to die.

Neuropsychological models of suicide remain preliminary, possibly the result of significant symptom and co-morbid heterogeneity among suicidal individuals. Depression and ADHD (Davids & Gaspar, 2005) are highly co-morbid with BPD, such that cognitive functions may overlap. While NP studies of suicide have focused on depressed samples, not all those
suffering from depression are suicidal and not all suicidal individuals are depressed. Biological vulnerabilities or trait-like predispositions are proposed to increase the risk for suicide beyond that due to psychiatric illness (Mann, 2003). While the overt behaviours and personality traits of suicide risk have been studied more in BPD, the underlying cognitive deficits that may constitute a biological vulnerability for suicide risk are unknown. Neuro-imaging evidence suggests that the dorsolateral prefrontal cortex (DLPFC), the anterior cingulate (ACC), and the orbitofrontal cortex (OFC/VMPFC) are three functional domains of the PFC that regulate the EFs of working memory, inhibitory control, interference control, and complex decision making. These specific EFs are reported as compromised among BPD subjects (Ruocco, 2005; LeGris & van Reekum, 2006).

**Working Memory**

Working memory is primarily under the control of the DLPFC (Goldman-Rakic, 1993) and represents the storage and manipulation of information in short-term memory. Working memory is critical for the regulation of future behaviour (Baddeley, 1996) and influences decision making (Bechara et al., 2001). Auditory working memory impairment is evident in some BPD samples (O’ Leary 1991; Kurtz & Morey, 1999; Monarch et al., 2004) but not in others (Dinn et al., 2004; Sprock et al., 2000; Judd & Ruff, 1993). A link between working memory and suicidal behaviour has been reported in affective disorder patients (Swann et al., 2005; Raust et al., 2007), but this relationship has not been tested in BPD.

**Inhibitory Control**

Behavioural impulsivity is strongly linked to suicide risk in BPD (van Links et al., 2000; Soloff et al., 2000; Brodsky et al., 1997); however, not all studies support these associations (Yen et al., 2009). Although lacking, different inhibitory mechanisms that drive impulsive behaviour need to be identified and may explain the poor correlations among measures of impulsivity and inhibitory control (Nigg, 2000). Stroop performance represents a type of cognitive interference control requiring selective attention and suppression of an initial prepotent response to distracting or competing stimuli. Motor response inhibition, as assessed by Stop Task performance, requires the ability to stop suddenly and completely an ongoing thought or action once initiated. Deficits in interference control and motor inhibition (Go/No-go tasks) are frequently but not consistently evident in BPD (LeGris & van Reekum, 2006). Preliminary
relationships between poor cognitive control and suicide have been implicated (Becker et al., 1999; Keilp et al., 2001; Raust et al., 2007), but these associations have not been examined in BPD. Interference control is frequently associated with the DLPFC and ACC regions of the brain (Audenaert et al., 2001; Stuss et al., 2001), while stop/go tasks represent DLPFC (Logan, 1994) and OFC functions (Horn et al., 2003; Mann, 2003).

**Decision Making**

Decision making is a complex executive function primarily linked to the orbitofrontal regions, including the ventromedial cortex (Dunn et al., 2006; Jollant et al., 2010), and decision making has been consistently impaired in all BPD samples tested to date (Bazanis et al., 2002; Dougherty et al., 2004; Kirkpatrick et al., 2007; Haaland & Landro, 2007). Iowa Gambling Task (IGT; Bechara et al., 1994) performance represents a type of emotionally biased decision making that has been linked to suicidal behaviour in non-BPD samples (Jollant et al., 2005; Malloy-Diniz et al., 2009). Individuals who perform poorly on the IGT demonstrate significant decisional impairment in their daily lives. In addition, the effects of other executive functions on impaired IGT performance continue to be debated (Maia & McClelland, 2004; Bechara et al., 2005; Fellows & Farah, 2005). Given the affective and behavioural instability of BPD, which may be reflected in their impaired decision making, amid growing evidence of ventromedial and amygdala irregularities (Tebartz van Elst et al., 2003; Lis et al., 2007; Silbersweig et al., 2007), it is anticipated that “hot” or emotional IGT decision making would be more strongly linked to suicide risk than would the “cool” or unemotional EF of working memory, interference control, or motor inhibition. An understanding of the unique hot or cool executive functions that may contribute to greater suicide risk in BPD has important clinical implications for more targeted assessments and treatments.

This study compares a variety of EFs in women with BPD relative to healthy controls, using laboratory tasks known to be localized to the “cool” DLPFC and “hot” VMPFC regions. The sensitivity of EF to suicide risk in BPD was tested. Suicide risk, the primary outcome, was estimated by the self-reported Suicidal Behaviour Questionnaire-Revised (Osman et al., 2001), assessing past, present, and the likelihood of future suicidal behaviour. An exploratory analysis of the individual behaviours comprising total suicide risk scores was also conducted. As self-rated depression is a salient risk for suicide and is highly co-morbid with BPD, EF and suicidal risk are examined in addition to current levels of depression. It was expected that (1) IGT
performance would be more impaired in BPD women relative to controls beyond that explained by depression and possibly other EF; (2) IGT decision-making impairment would be more strongly associated with greater suicidal risk than interference control, motor inhibition, or working memory; and (3) deficits in motor control would contribute to suicide risk consistent with the associations of behavioural impulsivity and suicide. As no prior study of BPD has examined this combination of EFs and their associations with suicide risk, this study is exploratory in nature. Furthermore, no known study has examined the relationship of Stop Task performance (Logan, 1994) and suicide risk in any high-risk population.

Methods

Participants

Participants were 83 community dwelling females between 18 and 51 years of age; 42 had a confirmed diagnosis of BPD and the remaining 41 were free from any mental or physical health problems. Participants with BPD were recruited from an ongoing randomized treatment trial at two university hospitals in Toronto, Ontario, Canada. Healthy controls were acquired through advertising targeting hospital staff and health science students. Eligibility was determined by a standardized telephone screening. Full ethics approval was granted by both hospitals.

Diagnoses were confirmed in patients using the Structured Clinical Interview for DSM-IV, Axes I (SCID-I) (Spitzer et al., 1990) and the International Personality Disorder Examination (IPDE) (Loranger, 1995), as required of the clinical treatment trial. They were conducted by PhD-level clinicians and a certified psychiatrist (McMain et al., 2009). BPD participants had completed one year of DBT, versus standard psychiatric care, and they were in bimonthly or monthly follow-up with their mental health providers. To ensure current BPD status, patients required a minimum of 6/10 on the McLean Screening Instrument (MSI-BPD) (Zanarini et al., 2003). A score of 7 is both sensitive (.81) and specific (.85) for BPD. BPD participants on prescribed psychotropics were eligible if stabilized on current medication; that is, they were not experiencing any unusual side effects or changes to their medications for four weeks prior to testing. All participants were English speaking. Excluded from the study were those with current or previous schizophrenia, bipolar disorder, major psychosis, or known neurological diseases, including serious head injury involving a loss of consciousness. BPD participants with
current clinical depression or those treated for substance dependence/abuse within four months of testing were excluded. Controls with any psychiatric history or scoring > 2/10 on the McLean screen were ineligible. Controls were not assessed with SCID or IPDE interviews.

**Procedures**

Measures were administered individually in a single session lasting three to four hours. Instructions for all tasks were standardized and scripted. To lessen the emotional effect on task performance and to ensure blinding to current suicidal status, performance tasks preceded self-report measures. A clinician/PhD trainee, administered measures to 76 participants, and a trained RA administered measures to seven controls. Affective and suicidal screens were completed by all participants. Co-morbidity data were acquired through semi-structured interviews. BPD participants completed measures without obvious distress. All participants received a full written description of the study, provided written consent, and received a nominal fee for the completion of the measures.

**Performance Measures**

The IOWA Gambling Task (IGT) (Bechara et al., 1994) assesses the uncertainty and ambiguity of reward-punishment probabilities on a series of 100 card selections. Participants must relinquish short-term gain in favour of longer term profit and learn from their experiences on the task. The computerized version (Bechara et al., 2001) involved four card decks (A, B, C, and D) that appeared face down on the monitor. Participants selected as frequently as they wished from any deck to maximize profit on a $2,000 loan of play money. Decks A and B were disadvantageous decks that resulted in a net loss. Decks C and D were advantageous decks, resulting in a net gain. Participants were uninformed of when IGT completion would occur, but they were warned that some decks were worse than others were; they were instructed to avoid the worst decks. The main dependent variable was the total advantageous card selections (Decks C + D) minus the disadvantageous card selections (Decks A + B) on 100 trials. Higher scores reflect more advantageous decisions. A score of 10 or more represents normal decision making.

The Digit Span of the Wechsler Adult Intelligence scale, 3rd revision (WAIS-III) (Wechsler, 1997) assessed short-term verbal working memory requiring the accurate recall of digit sequences in forward (storage) and backward (manipulation) conditions. On both tasks, the examiner read aloud a series of number sequences of increasing difficulty. Each sequence
consisted of two trials with the same number of digits. Two points were awarded for correct responses on both trials. One point was awarded for one correct trial and zero points are received if both trials are incorrect, at which time the test is discontinued. The maximum score for forward recall is 16, and for backwards recall is 14, totalling 30 points. Total digit scores were used in this study.

Two measures of executive inhibition assessed the ability to intentionally withhold or suppress attention or response to competing stimuli in order to achieve higher order goals (Nigg, 2000). The Victoria Stroop Task (VST) (Strauss et al., 2006) involved three reaction time conditions (colour naming, word reading, and incongruent colour word naming) depicted on separate pages of 24 coloured rectangles/words aligned in four columns of six rows. Participants quickly read colours or words without making errors. Interference control typically represents the difference in time to name colours from the time of naming the ink of incongruently coloured words. (For example, the word “green” printed in blue, and the participant must repress the automatic urge to say green.) Ratio interference scores (cw/c) are recommended if cognitive slowing is suspected (Troyer et al., 2006). As the reaction times of BPD women were longer on all Stroop conditions relative to controls, some cognitive slowing was suspected, which resulted in the use of ratio interference scores as the primary variable. Response interference taps selective attention to conflicting requirements and the deliberate control or inhibition of interfering information (Henik & Salo 2004). Longer Stroop reaction time, measured in seconds, represents poorer interference control.

Motor inhibition was estimated by the computerized Stop Signal Task (Logan, 1994). Participants pressed designated left or right mouse keys when go signals, represented by an X or an O, appeared on the monitor, and they inhibited this response when an auditory warning sounded, which occurred randomly on 25% of the trials. The auditory tone sounded at variable delays (Stop Signal Delay or SSD) following the appearance of the go signal. A pre-programmed timing of the tone was increased or decreased by 50 milliseconds to ensure success on 50% of the stop trials. The difference between the time to execute the go and the titrated SSD estimated the stop time (SSRT), which was the primary variable. Five blocks of 48 trials were administered following a practice trial. Data on the final four blocks comprising 192 trials were analyzed. Because initial SSD started at 250 ms. and may have been far from the SSD values after titration, the first 48 trials were discarded. Longer SSRT represents weaker inhibition.
Raven’s Progressive Matrices (SPM) (Raven et al., 2003) provided an estimate of intellect believed to be independent of language and formal schooling. Sixty items, arranged in sets of 12, contained a figure with a missing piece. Participants selected from six or eight alternates to complete the figure, only one of which was correct. Each set involved a different principle for obtaining the missing piece with items arranged in increasing difficulty. One point was awarded for each correct item. The Test of Word Reading Efficiency (TOWRE) (Torgesen et al., 1999) provided an index of reading ability involving the number of words accurately read (sight word) and pronounced (phonemic decoding) in 45 seconds. A standardized reading efficiency score based on both sub-test scores was calculated. This screen is sensitive to more complex reading tasks, minimizes the effects of culture and ethnicity, and detects learning disability in adults. Preliminary evidence has linked suicide and non-verbal learning disability (Rourke et al., 1989; Bender et al., 1999).

**Self-Report Measures**

The Suicide Behaviour Questionnaire-R (SBQ-R) (Osman et al., 1998) is a forced choice questionnaire comprising four items assessing past, current, and the likelihood of future suicide behaviour. Respondents selected one response from each of four items. Item 1 tapped lifetime suicide ideation and/or attempts (scored 1 to 4). Item 2 assessed the frequency of suicidal ideation over the preceding 12 months (1-5). Item 3 captured the threat of suicide attempt (1-3) indexed by ever informing others of suicidal plan or intent. And, Item 4 evaluated the self-reported likelihood of future suicide attempts (rated 0-6). The total SBQ-R score, ranging from 3 to 18, was the primary dependent variable with higher scores representing greater risk. A cut off of 8 on the SBQ-R demonstrates excellent sensitivity (85%) and specificity (91%) for distinguishing suicidal and non-suicidal adolescents and adults (Osman et al., 2001). Separate item subtotals of the SBQ-R were also examined in a secondary exploratory analysis. This scale is found in Appendix B.

The 21-item Beck Anxiety Inventory (BAI) (Beck et al., 1988) and the Beck Depression Inventory II (BDI) (Beck et al., 1996) assessed participants’ current affective states, which can interfere with cognitive performance. Items were rated from 0 (absence) to 3 (severe) with higher scores representing greater severity. The 54-item Attention Deficit Scale for Adults (ADSA) (Trioli & Murphy, 1996) assessed symptoms of Attention Deficit Disorder where one of five categories for each item (never, seldom, sometimes, often, or always) was endorsed. Total
ADSA Scores were analyzed. As validated by Trioli and Murphy (1996), a score of 181 or more represents moderate to severe ADHD. This measure also assesses several components of impulsive behaviour (Dowson et al., 2004). The Borderline Evaluation of Severity over Time (BEST) (Pfohl & Blum, 1997) estimated BPD severity within the preceding seven days, involving recent thoughts and feelings and negative and positive behaviours rated on a five-point scale (1 = none/slight and 5 = extreme). Scores were reversed for positive behaviour. Composite scores, ranging from 12 to 72, comprised the total severity score, plus 15 points. Higher scores represent greater BPD severity.

Data Analyses

Raw data, excepting the standardized reading scores, were used for statistical analyses using the Statistical Package for the Social Sciences 13. Results were based on the uncorrected data sets and a near full sample size with the following exceptions. Due to unexplained technical error, three controls had incomplete Stop task data. One subject was missing IGT data. Two subjects did not complete BDI, BAI, or suicidal measures for unspecified reasons. Group differences were assessed using independent Student t-tests, analysis of variance for continuous variables, and Chi-square for categorical variables. Pearson Product Moment correlations assessed relationships among suicidal risk, EF, and the clinical characteristics. Analysis of suicide risk was restricted to BPD participants. Standard multiple regression analyses, excluding all subjects with missing data, were used to identify the strongest EF predictors of suicide risk. Transformed Stroop interference scores were used in the analyses of the BPD sample to correct a positively skewed distribution. Due to the exploratory nature of this study, significance was set at <.05.

Results

Demographic and Clinical Characteristics

Eighty-five percent of BPD participants endorsed one to four prior Axis I disorders. Most of them experienced two anxiety related co-morbidities: Post Traumatic Stress Disorder (n=10), Social Phobia (n=8), Panic Disorder (n=8), General Anxiety Disorder (n=7), and OCD (n=5). A history of depression was reported by 71% of BPD participants, 24% experienced dysthymia, and 29% suffered from prior eating disorders. Known co-morbid personality
disorders were dependent ($n=3$), avoidant ($n=3$) schizotypal ($n=1$), passive aggressive ($n=2$), antisocial ($n=2$), and paranoid ($n=1$). Few participants reported any problems with ADHD: three participants suspected childhood ADHD, but only one was formally diagnosed. No participant reported a learning disability. Fifty percent of the BPD sample ($n=21$) experienced prior substance abuse involving alcohol, alcohol and stimulants, stimulants alone, cannabis, or prescription drugs. The majority of BPD participants had completed the treatment requirements of the RCT and were receiving standard follow-up care that involved bimonthly or monthly visits to their mental health care provider.

Sample characteristics are depicted in Table 5.1. Groups were similar in age and Canadian born status, but they differed significantly on years of education. Seventy-six percent of BPD participants were stabilized on prescribed psychotropics. Ten were un-medicated, nine were taking antidepressants, 13 were on antidepressants and anxiolytics, and five individuals were taking antidepressants, anxiolytics, and neuroleptics. Five others were prescribed mood stabilizers, antidepressants, anxiolytics, and neuroleptics. Eighty-eight percent of BPD participants exceeded the score indicative of suicide risk (SBQ-R >8). The mean suicide scores of BPD participants (13.3, ±3.6) exceeded the norms of suicidal adult inpatients (11.2, ±4.0) as validated by Osman et al. (2001). Seventy-one percent of women with BPD endorsed low to moderate anxiety, while 68% were mildly to moderately depressed. Attention deficits differed significantly among groups, but the mean ADSA scores of the BPD group were shy of the cut off representing moderate to severe ADHD. The reading efficiency scores of BPD participants fell within the 17th percentile, representing below average performance.
Table 5.1
Demographic, Clinical, and EF Characteristics of Women with BPD and Healthy Controls

<table>
<thead>
<tr>
<th>Demographics</th>
<th>BPD</th>
<th>Healthy Controls</th>
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<tbody>
<tr>
<td>Age M (SD)</td>
<td>32.2 10.5</td>
<td>31.2 (9.0)</td>
</tr>
<tr>
<td>Education M (SD)</td>
<td>15.5 (2.9)</td>
<td>15.6 (2.9)</td>
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<tr>
<td>Canadian Born</td>
<td>35</td>
<td>33</td>
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<th>Healthy Controls</th>
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<tbody>
<tr>
<td>BDI M (SD)</td>
<td>25.0 (13.9)</td>
<td>4.3 (4.8)</td>
</tr>
<tr>
<td>BAI M (SD)</td>
<td>24.0 (14.6)</td>
<td>6.5 (6.3)</td>
</tr>
<tr>
<td>SBQ-R M (SD)</td>
<td>13.3 (3.6)</td>
<td>3.8 (1.1)</td>
</tr>
<tr>
<td>Towre SW M (SD)</td>
<td>88.0 (12.8)</td>
<td>95.5 (7.2)</td>
</tr>
<tr>
<td>Towre PD M (SD)</td>
<td>46.8 (13.7)</td>
<td>55.4 (5.9)</td>
</tr>
<tr>
<td>Towre Total (z)</td>
<td>90.3 (15.6)</td>
<td>101.9 (10.2)</td>
</tr>
<tr>
<td>ADSA Total M (SD)</td>
<td>177.8 (20.1)</td>
<td>135.3 (20.3)</td>
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<tr>
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<th>Healthy Controls</th>
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<tr>
<td>Education M (SD)</td>
<td>15.6 (2.9)</td>
<td>15.6 (2.9)</td>
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<tr>
<td>Canadian Born</td>
<td>35</td>
<td>33</td>
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<tr>
<th>EF Measures</th>
<th>BPD</th>
<th>Healthy Controls</th>
</tr>
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<tr>
<td>Digit Span M (SD)</td>
<td>16.5 (3.9)</td>
<td>18.6 (4.2)</td>
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<td>SSRT (ms) M (SD)</td>
<td>256.3 (93.6)</td>
<td>233.8 (55.1)</td>
</tr>
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<td>Ravens Matrices M (SD)</td>
<td>46.8 (11.0)</td>
<td>50.4 (7.0)</td>
</tr>
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<td>Net IGT M (SD)</td>
<td>-.71 (30.2)</td>
<td>21.07 (30.3)</td>
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<tr>
<td>Colour word M (SD)</td>
<td>26.8 (11.9)</td>
<td>21.2 (4.3)</td>
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<tr>
<td>Interference iii-i</td>
<td>13.6 (9.0)</td>
<td>9.8 (4.3)</td>
</tr>
<tr>
<td>Interference iii/i</td>
<td>1.04 (7.7)</td>
<td>.91 (.5)</td>
</tr>
</tbody>
</table>

Net IGT = Iowa Gambling Task (C+D – A + B); Stroop = Victoria Version; Digit Span = Digits Forward + Digits Back of the WAIS; Raven’s Matrices = Standard Progressive Matrices; ADSA = Attention Deficit Scale for Adults; SSRT = Stop Signal Reaction Time; SBQ-R = Suicide Behaviour Questionnaire – Revised; Towre SW = speed of word reading; Towre PD = speed of phonetic decoding; Towre Total = standardized sum of word reading and phonetic decoding; BDI = Beck Depression Inv II; BAI = Beck Anxiety Inventory.

**EF Performance**

EFs and other cognitive abilities were compared. Initial group differences in total working memory, all baseline Stroop and interference difference (cw-c) scores, were significant. Given that response times on all Stroop conditions were more delayed in BPD women relative to controls, indicative of generalized slowing, an interference ratio score was also calculated (cw/c), which compensates for cognitive slowing (Troyer et al., 2006). This score did not differ among groups. Strong group differences in decision making were evident (Cohen’s $d = 0.72$). Groups were similar in stop task reaction time with mean group values reflective of normal range.
performance (Williams et al., 1999). Nor did the groups differ in intellectual function. Because education levels differed, education was co-varied in a series of ANCOVAs performed on each EF. Group differences in Stroop colour \((F[2,82] = 1.81, P= 0.18)\); word \((F[2,82] = 1.84, P = 0.18)\); incongruent colour/word, \((F[2,82] = 3.31, P = 0.07)\); interference difference \((F[3,79] = 2.33, P = 0.13)\); and working memory performance \((F[2,82] = 1.87, P = 0.18)\) became non-significant. However, decision making differences among groups remained significant with education \((F[2,79] = 6.92, P = 0.01)\) and IQ and education controlled \((F[3,78] = 5.81, P = 0.02)\).

Fifty percent of the BPD sample suffered from prior substance abuse/dependence; however, no differences on any EF, reading ability, ADSA scores, or suicidal measures (total and four sub-scores) were found among BPD subjects with and without such history. BPD women with \((M = -2.50, SD = 6.6)\) and without substance abuse history \((M = .33, SD = 7.0, P = 0.77)\) performed similarly on the IGT. To address whether psychotropic medications affected IGT performance, a one-way ANOVA was conducted with the BPD sample categorized in five groups according to the classes of medications prescribed \([0 – no meds, 1 = antidepressants, 2 = antidepressants and anti-anxieties, 3 = antidepressants, anti-anxieties plus neuroleptics and 4 = the previous three classes + anticonvulsants]\). No significant differences in IGT performance were evident among unmedicated BPD participants and those on any combination of psychotropics, \([F (4,36)= 1.25, P = 0.31]\).

**Correlates of Total Suicidal Risk in Women with BPD**

Zero order Pearson correlation coefficients of cognitive function and suicidal risk in BPD participants are depicted in Table 5.2. Due to the strong associations of IQ to both decision making and Stroop interference, IQ was controlled using partial correlations. There were no significant associations between total suicide risk and decision making with or without control for IQ. Stroop interference was inversely related to overall suicide risk \((r = -0.38, P = 0.02)\) and lifetime suicide attempt \((r = -0.47, P< 0.01)\), and it remained unchanged with IQ controlled. Working memory \((r = -0.02, P = 0.46)\), intelligence \((r = 0.09, P = 0.29)\), and motor inhibition \((r = -0.11, P = 0.24)\) were not associated with total suicide risk scores. Neither attention deficit scores \((r = 0.11, P= 0.25)\) nor word reading efficiency \((r =0.05, P= 0.37)\) were significantly associated with total suicide risk. Depression was not significantly associated with any EF in
women with BPD. Neither education nor years of substance abuse was significantly associated with any EF, depression, or total suicidal risk.

Table 5.2
*Pearson Product Moment Correlations between Cognitive/Clinical Measures and Total Suicide Risk in Women with BPD (n = 40)*

<table>
<thead>
<tr>
<th>Measures</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SBQ-R total</td>
<td></td>
<td>.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. IGT</td>
<td></td>
<td>.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Digit Span</td>
<td>-.02</td>
<td>.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. SSRT</td>
<td>-.11</td>
<td>.19</td>
<td>-.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Stroop Interference</td>
<td>-.38*</td>
<td>-.33*</td>
<td>-.21</td>
<td>.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Raven’s Matrices</td>
<td>.09</td>
<td>.59**</td>
<td>.46**</td>
<td>-.10</td>
<td>-.65**</td>
<td>-.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. BDI</td>
<td>.44**</td>
<td>-.07</td>
<td>-.19</td>
<td>-.02</td>
<td>.09</td>
<td>-.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. BAI</td>
<td>.33**</td>
<td>-.03</td>
<td>.17</td>
<td>-.08</td>
<td>-.15</td>
<td>.26</td>
<td>.63**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. BPD Severity</td>
<td>.34**</td>
<td>-.05</td>
<td>-.11</td>
<td>-.09</td>
<td>.02</td>
<td>-.04</td>
<td>.74**</td>
<td>.68**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Substance Abuse Hx</td>
<td>-.10</td>
<td>-.05</td>
<td>-.18</td>
<td>.17</td>
<td>-.11</td>
<td>.16</td>
<td>-.06</td>
<td>-.03</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>11. Education (yrs)</td>
<td>-.10</td>
<td>.16</td>
<td>.25</td>
<td>-.05</td>
<td>-.13</td>
<td>.30</td>
<td>-.06</td>
<td>-.02</td>
<td>-.05</td>
<td>-.17</td>
</tr>
</tbody>
</table>

*p < 0.05 (2-tailed); **p < 0.01 (2-tailed)

SBQ-R = total suicide risk score; IGT = decision making; Victoria Stroop Interference = Stroop 3/Stroop 1; SSRT = motor inhibition; Digit span = working memory; BDI = Beck depression inventory; BAI = Beck Anxiety Inventory; BPD severity = Borderline Evaluation of Severity over Time (BEST).

**Predictors of Suicide Risk in Women with BPD**

Simultaneous multiple regression analyses assessed the relative contributions of all EF on the prediction of suicide risk. In preparation for multivariate analyses, collinearity among the predictors of suicide risk was examined. Attention deficit (ADSA) and depression ($r = 0.37$, $P = 0.015$) and ADSA and BPD severity scores ($r = 0.44$, $P = 0.005$) were moderately correlated. BPD severity and depression were strongly correlated ($r = 0.74$, $P = 0.001$) as were depression and anxiety ($r = 0.631$, $P = 0.001$). As depression was also the strongest correlate of overall suicide risk, depression was considered the primary clinical predictor. To ensure a case-to-variable ratio of approximately 10-to-1, a maximum of four predictors could reasonably accommodate 39 BPD subjects because three BPD participants with incomplete data were eliminated from all regression analyses.

Net IGT decision making, transformed Stroop ratio interference scores, motor inhibition, working memory, and depression were initially entered simultaneously into a standard multiple regression model. Assumptions of normality, linearity, homoscedasticity, and the homogeneity of regression slopes were met. Despite the weak correlations of some EFs to suicide risk, all EFs were forced into the model as guided by the study hypotheses. The final model depicted in Table 5.3 excludes working memory because of a very weak relationship between working memory...
and total suicide risk. Stroop interference significantly explained total suicide risk, demonstrating near equivalent and independent contributions to that of depression. In order of importance, depression, interference control, motor inhibition, and decision making explained 34% of the adjusted variance in total suicide risk. Contrary to expectations, decision making and response/motor inhibition were deleted as significant predictors of overall suicide risk.

Table 5.3
Predictors of Total Suicide Risk in Women with BPD (n = 39)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDI</td>
<td>.13</td>
<td>.04</td>
<td>.06</td>
<td>.199</td>
<td>.48**</td>
</tr>
<tr>
<td>Net IGT</td>
<td>-.01</td>
<td>.02</td>
<td>-.04</td>
<td>.03</td>
<td>-.04</td>
</tr>
<tr>
<td>Stroop a</td>
<td>-7.76</td>
<td>2.32</td>
<td>-12.47</td>
<td>03.9</td>
<td>-.46**</td>
</tr>
<tr>
<td>SSRT</td>
<td>-.02</td>
<td>.01</td>
<td>0.02</td>
<td>.01</td>
<td>-.10</td>
</tr>
<tr>
<td>Constant</td>
<td>10.96</td>
<td>1.95</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| a = log transformed Stroop interference ** p <0.01
| F(4,34) = 5.95, P= 0.001
| r² = .41, adj r² = .34
| Note: untransformed Stroop (B = -2.53, SE -.80; β = -.45, CI = -4.16 to -.91); adj r² = 33% |

Poor collinearity tolerance between depression and BPD severity prevented these variables from entering jointly, thus requiring a separate regression analysis with BPD severity replacing depression. In this model, Stroop interference (β - 0.40, P= 0.01) now exceeded the contributions of BPD severity (β = 0.33, P= 0.03), decision making, and motor inhibition. Collectively, these four variables accounted for 21% of the adjusted variance of overall suicide risk, F(4, 34) = 3.48, P = 0.02.

An exploratory analysis of the EF contributions to each of the four item sub-scores of the SBQ-R total score was also undertaken. Results are depicted in Table 5.4 and Table 5.5. Stroop interference was significantly associated with reductions in lifetime suicide ideation/attempt, recent (12 month) suicide ideation/attempt, and the self-reported likelihood of future suicide attempt. Working memory was significant only for informing others of one’s suicidal plan or intent, but this model was insignificant. Importantly, 25% the adjusted variance in lifetime
suicide ideation/attempt was primarily explained by normal range Stroop interference control ($\beta = -0.41; P=0.01$) with depression deleted. This finding is noteworthy considering that lifetime suicide attempt remains the strongest predictor of future attempts (Soloff et al., 2000, 2003; Oquendo et al., 2003). Decision making did not predict any suicide risk despite the acceptable collinearity tolerance among all the variables in the models. When these analyses were repeated with BPD severity replacing depression, the results remained similar (Table 5.5). BPD severity made the largest, though non-significant, contribution to the likelihood of future suicide attempt, and significantly predicted recent suicide ideation/attempt. Stroop ratio interference control was significantly and inversely related to lifetime suicide ideation/attempt with other EFs and BPD severity deleted. To confirm the relationship of normal Stroop interference control and a reduction in suicide risk, regression analyses were repeated using the untransformed Stroop ratio scores, the Stroop interference difference scores, both with and without outliers removed, and the pattern of inverse associations held. Moreover, when compared with age-related Canadian population norms (Troyer et al., 2006), the mean Stroop ratio interference score of the BPD group was deemed average with a scaled score of 10.
Table 5.4
Exploratory Simultaneous Regression of EF predicting Suicide Risk Behaviours in Women with BPD, controlling for depression (n= 39)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Self-reported Likelihood of Future Suicide Attempt&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Ever Inform Others of Suicidal Plan or Intent&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Lifetime Suicide Ideation/Attempt&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Suicide Ideation in the Past 12 Months&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDI</td>
<td>.06 (.02) .41**</td>
<td>.01 (.01) .14</td>
<td>-.00 (.01) -.10</td>
<td>.05 (.01) .47**</td>
</tr>
<tr>
<td>Stroop Interference&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.7(1.3) -.31*</td>
<td>-9.4 (.64) -.24</td>
<td>-1.08 (.39) -.41**</td>
<td>-2.43 (.89) -.41**</td>
</tr>
<tr>
<td>Net IGT</td>
<td>.00 (.01) .03</td>
<td>-.00 (.01) -.14</td>
<td>.00 (.00) .19</td>
<td>-.00 (.01) -.09</td>
</tr>
<tr>
<td>SSRT</td>
<td>-.01 (.00) -.19</td>
<td>-.00 (.00) -.15</td>
<td>.00 (.00) .14</td>
<td>-.00 (.00) -.11</td>
</tr>
<tr>
<td>Digit Span Total Constant</td>
<td>-.08 (.07) -.17</td>
<td>.08 (.04) .36*</td>
<td>.02 (.02) .14</td>
<td>-.00 (.01) -.10</td>
</tr>
<tr>
<td>Fit of model</td>
<td></td>
<td></td>
<td>r² = .31, adj r² = .21</td>
<td>r² = .35, adj r² = .25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F(5,33) = 3.0*</td>
<td>F(5,33) = 2.1</td>
</tr>
</tbody>
</table>

* p<0.05, ** p<0.01, ns = p>0.05

SSRT = motor inhibition; Stroop = Interference Control; BDI = Beck Depression Inventory; IGT = net decision making; Digit Span = working memory
<sup>a</sup> = log transformation of Stroop ratio (cw/c)
<sup>b</sup> = individual summed items comprising Suicidal Behaviour Questionnaire (SBQ-R)
### Table 5.5
**Exploratory Simultaneous Regression Analysis Predicting Suicide Risk Behaviours in Women with BPD, controlling for BPD severity (N = 39)**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Self-reported Likelihood of Future Suicide Attempt&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Ever Inform Others of Suicidal Plan or Intent&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Lifetime Suicide Ideation/Attempt&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Suicide Ideation in the Past 12 Months&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>B (SE)</strong></td>
<td><strong>β</strong></td>
<td><strong>B (SE)</strong></td>
<td><strong>β</strong></td>
</tr>
<tr>
<td>BPD Severity</td>
<td>.04 (.03)</td>
<td>.28</td>
<td>.01 (.01)</td>
<td>.19</td>
</tr>
<tr>
<td>Stroop&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.31 (1.4)</td>
<td>-.27</td>
<td>-.85 (.63)</td>
<td>-.22</td>
</tr>
<tr>
<td>Net IGT</td>
<td>.00 (.01)</td>
<td>.07</td>
<td>-.00 (.01)</td>
<td>-.13</td>
</tr>
<tr>
<td>SSRT</td>
<td>.01 (.00)</td>
<td>-.21</td>
<td>-.00 (.00)</td>
<td>-.15</td>
</tr>
<tr>
<td>Digit Span Total</td>
<td>-.10 (.08)</td>
<td>-.23</td>
<td>.07 (.03)</td>
<td>.35*</td>
</tr>
<tr>
<td>Constant</td>
<td>4.78 (2.1)</td>
<td>1.16</td>
<td>3.24 (.59)</td>
<td>.35</td>
</tr>
</tbody>
</table>

*Fit of model*:  
- $r^2 = .21, \quad \text{adj } r^2 = .11, \quad F(5,33) = 1.97, P = .11$  
- $r^2 = .26, \quad \text{adj } r^2 = .14, \quad F(5,33) = 2.26, P = .07$  
- $r^2 = .35, \quad \text{adj } r^2 = .25, \quad F(5,33) = 3.52*, P = 0.01$  
- $r^2 = .27, \quad \text{adj } r^2 = .16, \quad F(5,33) = 2.42*, P = 0.05$

<sup>**p<0.05,   **p<0.01</sup>  
SSRT = motor inhibition; Stroop = Interference Control; BDI = Beck Depression Inventory; IGT = net decision making score; Digit Span= auditory working memory  
a = log transformed Stroop ratio (cw/c)  
b = individual summed items comprising Suicidal Behaviour Questionnaire Revised (SBQ-R)

### Discussion

EF performance was compared in healthy controls and recently treated outpatient women with BPD. Emotional decision-making deficits were present in women with BPD, despite their normal range DLPFC EF performance. IGT deficits in BPD women appear to be separable from other EFs, as proposed by the Somatic Marker Hypothesis (Bechara et al., 1994). Furthermore, IGT deficits were not attributed to current psychotropic use, self-reported depression, or a prior history of substance abuse. However, IGT performance and motor inhibition were not associated with any suicide risk in women with BPD. Nonetheless, normal range-stopping ability in the current sample prevents firm conclusions about the relationship of impaired motor control and suicidal risk in BPD women. Working memory contributed the least to suicide risk and confirmed earlier findings in depressed patients (Raust et al., 2007). Weaker, though normal, interference control was highly sensitive to overall suicide risk and was the sole predictor of lifetime suicide ideation/attempt beyond that explained by depression or BPD severity. As
lifetime attempt is the strongest predictor of future suicide attempts, these findings may be clinically important. As expected, self-reported depression contributed to a greater suicide risk (Soloff et al., 2003), despite the mean depression levels of BPD women being short of the threshold indicative of clinical impairment (Arnau et al., 2001). The dysthymia of BPD may have weakened executive control processes relative to healthy controls; however, these mood differences were inseparable from a diagnosis of BPD. As is commonly reported (Friedman et al., 2006), IQ estimates were associated with most EF measures in this sample. Women with BPD were deemed to be reasonably well educated with their mean Raven IQ scores identical to a recently published healthy control group (Malloy-Diniz et al., 2009); however, the educational differences among groups may have contributed to greater variance of EF performance in BPD women.

Present findings differ from formerly depressed suicide attempters (Jollant et al., 2005), where IGT deficits distinguished attempters from non-attempters irrespective of depression, lifetime suicide attempts, or violent or non-violent attempts. Interestingly, poor IGT performance and errors on the incongruent condition of the Stroop Task also distinguished bipolar patients with lifetime suicide attempts from those without attempts (Malloy-Diniz et al., 2009). Suicide risk, as estimated by the SBQ-R in the present sample, does not strongly distinguish suicidal ideation from attempt and may explain the absence of IGT associations and suicide risk versus the presence of IGT associations with suicide attempt history as previously reported. Stroop interference scores in the bipolar sample were not calculated (Malloy-Diniz et al., 2009), and the absence of uncorrected (incongruent) errors in the BPD sample further challenges comparisons of Stroop performance and suicide risk across samples. A significant inverse association between IGT performance and Stroop interference in women with BPD suggests some shared variance among these two conflict tasks. As IGT deficits theoretically reflect an emotional sensitivity to immediate reinforcement, with ill regard of future consequences, we anticipated that the IGT decisional deficits of BPD women would be associated with greater suicide risk; however, this hypothesis was not supported. While both the ACC and OFC/VMPFC regions have been implicated in ambiguous decision making (Bush et al., 2002; Ernst et al., 2003b; Rogers et al., 1999), present findings may also suggest that the ACC, believed to primarily govern Stroop performance (Smith & Jonides, 1999), is more sensitive to the high risk contemplation of suicide relative to the brain regions that monitor the
processes of virtual monetary reward and loss (Bechara et al., 1994). Using fMRI, Cohen et al. (2005) found that the ACC was indeed more active during high-risk decisions and more inactive during low-risk decisions. This discovery may also explain the findings of weak associations of IGT decision making and suicide risk in our sample.

In refute of our final hypothesis, normal range motor control was unrelated to any other EF and all clinical ratings including suicide risk. Unlike the findings of Go/No-go deficits in euthymic suicidal patients (Raust et al., 2007), there was no significant association between normal range motor inhibitory control and suicide risk in BPD. Intact interference control versus intact motor control and reduced suicide risk in BPD is highlighted in the present findings. Although speculative, effective interference control of chronic or less frequent suicidal thinking may suggest that recently treated BPD women are increasingly receptive to more hopeful alternatives via their abilities to inhibit and/or monitor the errors of their suicidal thoughts. In this way, their suicidal schema becomes more penetrable. Conversely, deficits in the ability to suppress a strong, enduring, or impenetrable wish to die may reflect more serious risk of suicide, requiring even greater effortful control. Intact interference control in our BPD sample contrasts with deficits of Stroop interference control in depressed suicidal inpatients (Keilp et al., 2008), which appears to be consistent with Wenzel and Beck’s (2008) cognitive model of suicide in which an intense suicidal schema becomes impenetrable.

This is the first known report of normal range interference control in women with BPD that is associated with reductions in their suicidal risk beyond that explained by current depressive state, BPD severity, IGT decision making, working memory, or motor inhibitory control. Present findings complement results in depressed subjects (Keilp et al., 2008; Raust et al., 2007) where suicide severity was more strongly linked to poor interference control than was depression severity. Stroop interference and suicide risk associations in BPD women were even stronger than those observed in Keilp et al.’s (2008) high lethality depressed sample. While Keilp et al.’s (2008) subjects performed poorly on both the incongruent and interference conditions of the Golden Stroop, BPD women’s normal range performance on all Stroop conditions supports the sensitivity of both Stroop tasks to suicide behaviour in two high-risk populations.

In direct contrast to present findings in BPD, Raust et al. (2007) observed impaired cognitive and motor inhibitory control in their depressed suicidal sample; however, their
reward/learning or decisional processes remained intact. Motor control deficits and intact decision making may be specific for depressed patients versus BPD patients. Nevertheless, normal interference control and other EFs have also been reported in depressed suicidal patients relative to depressed non-suicidal patients (Marzuk et al., 2005). While definitive interpretations of EF performance remain challenging and potentially lacking in specificity (Moritz et al., 2001), the associations of interference control as measured by the Stroop and suicide risk are evident in unipolar, possibly bipolar (Malloy-Diniz, 2009), and now BPD patients. Collectively, these findings lend support for the notion that interference control may be more sensitive to suicidal risk than psychiatric disorder (Keilp et al., 2008).

Current findings require replication in treated and untreated samples of individuals with BPD. The use of a single suicidal risk measure may have produced ceiling effects that lacked the ability to discriminate a range of suicide risks. Study findings are limited by the cross-sectional design and the convenience sampling of recently treated subjects. Lack of formal assessment and accountability for Axis I and II co-morbidity is another limitation. Interestingly, Neves et al. (2009) examined co-morbidity and suicide risk in bipolar patients and found that co-morbid Borderline Personality Disorder carried the greatest risk of high lethality attempt when compared to all other co-morbidities. Individuals with Bulimia Nervosa and co-morbid BPD demonstrated greater Stroop and other EF deficits than did those patients with co-morbid depression (Bourke et al., 2006). Considering the high rates of suicide associated with BPD, it seems unlikely that secondary co-morbidity would overpower BPD as a primary diagnosis. However, future research should employ clinical comparisons to explore the specificity of these preliminary findings for BPD. Consistency in the methods of calculating Stroop interference control that accounts for baseline performance or cognitive slowing needs to be addressed by future researchers to produce convergent evidence of these preliminary, but important, associations.

To conclude, normal range interference control is implicated in reduced suicide risk in outpatient women with BPD. While the IGT and Stroop tasks share elements of decision making and conflict monitoring (Posner et al., 2002), the Stroop appears to be more sensitive to suicide risk in this sample. As suggested by Goudriaan et al. (2008), the mix and multiplicity of demands required of IGT performance may have further diluted the relationship of decision making and suicide risk. Deficits in interference control may represent a neuropsychological vulnerability for suicide that extends beyond psychiatric diagnosis.
Chapter 6: General Discussion

Persistent patterns of instability of affect, impulse control, and identity disturbance are core symptoms of BPD. As a result of these dysregulations in self-control, it was anticipated that deficits in executive functioning would be present in a relatively stable outpatient sample of women with BPD. Indeed, IGT decision-making deficits were present in 63% of the BPD sample, but these deficits were unrelated to their normal performance on tasks of working memory, interference control, and response inhibition. Based on these findings, it was expected that IGT decision-making deficits would also be associated with greater suicide risk; however, this hypothesis was not supported. Disadvantageous IGT performance was insensitive to any suicide risk in BPD women, 90% of whom were deemed to be at risk for suicide. Furthermore, normal range motor control, representing reduced impulsivity, was not associated with poor IGT decisions or suicide risk. However, interference control proved to be as sensitive to overall suicide risk as self-reported depression.

IGT Impairment in Women with BPD

IGT deficits corroborate previous lines of evidence using other decision tasks that together suggest that a sub-group of individuals with BPD may suffer from an impairment, similar to that observed in ventromedial lesioned patients. Theoretically, IGT deficits are proposed to represent difficulties in anticipating the future consequences of one’s choices as a result of deficient emotional or somatic signalling; however, without assessing somatic marker activation in BPD, the SMH interpretation of IGT deficits remain speculative. The decisional impairment in women with BPD may also represent a vulnerability for risk-seeking behaviour as an antidote to the chronic negative affect of the disorder or may represent an avoidance of the high frequency punishment card decks. Personality traits involving different facets of behavioural impulsivity or affective lability, that were not accounted for in this study, may also explain their IGT deficits. Without the use of physiological data or the variant version of the IGT, the unique mechanisms underlying IGT performance cannot be confirmed. Current findings do suggest that working memory and inhibitory control mechanisms as estimated by the Stroop and Stop Tasks are not associated with poor IGT decisions in this sample of women with BPD. While IGT impairment may also implicate inefficient learning of the various reward-
punishment contingencies on the IGT, normal IQ was inconsistently associated with IGT performance in this sample. IGT deficits in BPD and controls may have also been the result of the all female sample and the well educated control group because gender and higher education are believed to weaken IGT performance.

The group specific associations of intellect and motor control to IGT performance suggest that these cognitive processes may be unnecessary for advantageous decision making. Higher intellect may have compensated for other unknown factors explaining poor decisions in the patient group. Normal range stopping ability was positively associated with better decisions in the control group, possibly due to a speed/accuracy trade off. Scatter plot analyses revealed that 22 BPD women with mean SSRTs of 200-250 ms. performed disadvantageously on the IGT, whereas 18 healthy controls with similar stopping abilities (200-250 ms.) made advantageous decisions. An equal number of BPD and control subjects with even stronger motor control (i.e., SSRT <200ms) demonstrated both advantageous and disadvantageous IGT decisions, suggesting that improved stopping ability was not associated with better IGT performance. Similar results have been observed in pathological gamblers where neither Stroop interference deficits nor Go/No-go deficits predicted disadvantageous IGT performance (Kertzman et al., 2011).

Collectively, these findings contradict the notion that IGT performance primarily represents deficits in inhibitory control. Working memory was not associated with decisional impairment in BPD women or healthy controls and is consistent with former findings in alcohol, methamphetamine, and cocaine dependent subjects (van der Plas et al., 2009).

Poor decision making in women with BPD may be the result of deficient emotional inhibition as proposed by the SMH. Given that IGT performance is sensitive and specific to ventromedial and amygdala function (Stuss & Levine, 2002) and these particular brain regions are affected in BPD (Schmahl et al., 2003; Sweilsberg et al., 2007; Lis et al., 2009), IGT deficits may be the result of exaggerated emotional responses to immediate reward incentives. Long-term prospective studies of individuals with BPD have indicated that symptoms related to affective instability, such as poor interpersonal and social decision making, appear to persist well after other problematic symptoms of the disorder have remitted, and therefore, they may be more trait-like (Zanarini et al., 2007). Thus, IGT impairment may reflect a chronic trait that is more resistant to remission. This recently treated outpatient sample with selective hot IGT deficits and intact cool EFs may reflect this trajectory.
Interference Control and Suicide Risk

Stroop performance was sensitive to three of four suicide risk behaviours as assessed by the SBQ-R in BPD women. In contrast to other affective suicidal samples with interference control deficits and greater lifetime suicide attempts, BPD subjects with longer but intact interference control demonstrated reductions in their overall suicide risk, possibly the result of more time or attention needed to monitor the conflict of their suicidal thinking. The sensitivity of the Stroop to variations in suicide risk supports the need for a greater understanding of these preliminary, but potentially important, relationships. Present findings require replication in larger samples of BPD individuals who represent a more diverse range of suicide risk. Stroop performance may be useful clinically as an adjunct to the complex assessment of suicide risk.

How does one reconcile the associations of IGT decision-making deficits and BPD diagnosis and the absence of decision-making and suicide risk associations in the same study sample? The following interpretations may provide plausible explanations.

A consideration or act of suicide represents a highly negative or self-punishing outcome, while the possibility of winning money carries the expectation of a pleasurable event. These differences in emotional response are governed by different neural structures or substrates and neurotransmitter pathways. (Threat or negative emotion is generally perceived to be amygdala driven and primarily serotonin related, while pleasure or the anticipation of pleasure is often associated with the nucleus accumbens and the dopamine circuitries.) The Stroop and IGT tasks may differ in their sensitivity to positive or negative emotion and possibly the intensity of these emotions.

While the IGT and Stroop tasks share similarities of emotionally relevant decision making, these tasks also engage distinct cognitive control processes. For example, brain imaging studies suggest that during the incongruent condition of the Stroop, the anterior cingulate gyrus is most highly activated relative to other Stroop conditions (Stirling 2002). This suggests that this region is important for the wilful selection of appropriate responses and the inhibition of inappropriate ones. The Supervisory Attentional System (Norman & Shallice, 1986) is also associated with the anterior cingulate and is proposed to be more active during conditions of potential threat, danger, or significant risk, when careful planning is required and when there is a need to override a well-learned but inappropriate response. Thus, it would appear that the Stroop task may actively engage more attentional resources to monitor the risky decisions of suicide.
relative to the virtual losses on the IGT. This may also explain the very weak associations of IGT decision making and suicide risk.

Decisions affecting the uncertainty of monetary wins or losses obviously carry less risk than do the decisions or thoughts of ending one’s life. While the ACC and OFC regions are implicated in uncertain decision making (Bush et al., 2002; Ernst et al., 2004; Rogers et al., 2004), the ACC is more highly active during high-risk decisions (Cohen et al., 2005) and may explain the strong associations among interference control, representing ACC functions and suicide risk.

The multiplicity of cognitive processes embedded within the IGT relative to the Stroop may have diluted the relationships between IGT performance and suicide risk. Furthermore, the lack of structure and ambiguity of the IGT relative to the more structured, rule-driven, traditional “cool” EF tasks may have contributed to the decision deficits in women with BPD considering the dichotomous style of thinking that is frequently attributed to the disorder.

Areas of the ACC and the ventromedial prefrontal cortex are believed to regulate both cognition and emotion (Bush et al., 2000). Functional irregularities in one or both of these regions may explain the deficits of poor decision making and weaker yet normal range interference control in women with BPD.

**Study Limitations**

Limitations of the present findings include the convenience sampling of female participants, making generalizations difficult beyond treatment-seeking outpatient women with the disorder. The number of BPD participants and the lack of systematic control for the multiple co-morbidities and psychotropic medications may also compromise the generalizability of the findings. Axis I and Axis II co-morbidities beyond screens for depression, anxiety, and developmental disorders require more systematic assessment in future investigations. It remains unclear whether additional control for multiple co-morbidities would have altered the present results or were accounted for within the BPD diagnosis itself. Control of potential co-morbidity among the healthy subjects may have required the use of SCID I interviews; however, the control group performed normally on all of the clinical screens administered in this investigation. The use of self-reporting for current and past substance use without physiological confirmatory evidence may also have affected the findings.
The use of single estimates for all constructs, including suicidal risk, is a limitation of the present findings, but it was considered appropriate for exploratory purposes. The SBQ-R as a measure of suicide risk may have been insufficiently sensitive to variations in the severity of suicide risk in BPD individuals resulting in possible ceiling effects.

**Study Strengths**

A healthy control group was employed to improve the internal validity of the study design. Gender effects on EF were controlled as recommended. The study size demonstrated adequate statistical power to test the primary study hypotheses. The behavioural measures and laboratory tasks selected are well-established measures commonly used in NP investigations. Pilot testing of the study instruments and the use of standardized instructions with eligible BPD subjects ensured a consistent administration of measures. Control for relevant developmentally related co-morbidity and current levels of depression and anxiety was attempted. Cognitive task performance preceded all mood and behavioural self-report measures, keeping assessors blind to suicide history and limiting the possibility of undue emotional interference on cognitive task performance in participants. All data was collected during a single office visit. Attempts to ensure the statistical validity of the findings have been demonstrated.

**Implications for Future Research**

Concurrent use of impulsive and affective lability personality trait measures, as well as an assessment of “thinking out loud” processes, in future research designs may clarify the motivation and thinking of participants during IGT performance. Measurements of SCR activity would confirm the SMH hypothesis of IGT decision-making deficits in this population. The inclusion of the variant version of the IGT and/or less complex tasks of decision making may identify the unique mechanisms underlying poor decision making in women with BPD. Present findings require validation with samples representing a range of BPD severity, including those not seeking treatment. Larger samples would also permit the analysis of relevant confounds and the inclusion of psychosocial variables that may affect decision-making performance. For example, childhood sexual abuse has been implicated in the classification of BPD as a neurodevelopmental disorder. The additional use of risk seeking or risk avoidant behavioural questionnaires that complement experimental task performance may permit more confirmatory interpretations of laboratory based decisional deficits. Real world decisional assessments could
also be implemented, such as the Six Elements Tests (SET) (Shallice & Burgess, 1991) and the Multiple Errands Tests (MET) (Shallice & Burgess, 1991). The MET requires unstructured, time-limited functions conducted in a shopping mall, and it demonstrates specificity for ventromedial dysfunction (Tranel et al., 2007). These strategy application tasks may be superior to traditional neuropsychological tests at probing real world EF deficits.

Future researchers employing the Stroop task should consider the need for more consistency in the tasks selected as well as the methods of calculating interference control. Many studies have not accounted for baseline performance, have not calculated an interference score, or have used a variety of formulas to calculate Stroop interference. Consistency in these methods may lead to more convergent findings of the associations of Stroop interference control and suicide among high-risk populations.

The use of clinical comparison groups in future designs would confirm the specificity for EF deficits in women with BPD. Despite these limitations, the present study reflects an initial attempt to examine the associations among a variety of EFs and IGT decision-making deficits, and it explores the role of EF and suicide risk in a relatively homogeneous sample of adult women with BPD.
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Statistical Package for the Social Sciences, Version 13, Chicago, IL.


APPENDIX A

SBQ-R (Osman, 1998)

Identification #__________    Gender ________   Age______   Date__________

Instructions: Please circle the number beside the statement or phrase that best applies to you.

1. Have you ever thought about or attempted to kill yourself? (circle only one)
   1 = Never
   2 = It was just a brief passing thought

   3a = I have had a plan at least once to kill myself but did not try to do it
   3b = I have had a plan at least once to kill myself and really wanted to die

   4a = I have attempted to kill myself, but did not want to die
   4b = I have attempted to kill myself, and really hoped to die

2. How often have you thought about killing yourself in the past year? (circle only one)
   1 – Never   2 = Rarely (1 time)   3 = Sometimes (2 times)   4 = Often (3-4 times)   5 = Very often (5 or more)

3. Have you ever told someone that you were going to commit suicide, or that you might do it? (Circle only one)
   1 = No

   2a = Yes, at one time, but did not really want to die
   2b = Yes, at one time and really wanted to do it

   3a = Yes, more than once, but did not really want to do it
   3b = Yes, more than once, and really wanted to do it

4. How likely is it that you will attempt suicide someday? (Circle only one)

   0 = Never
   1 = No chance at all
   2 = Rather unlikely
   3 = Unlikely
   4 = Likely
   5 = Rather Likely
   6 = Very Likely

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