

Traumatic Brain Injury and Executive Functioning in an Incarcerated Sample

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TRAUMATIC BRAIN INJURY AND EXECUTIVE FUNCTIONING IN AN
INCARCERATED SAMPLE

by

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ABSTRACT
TRAUMATIC BRAIN INJURY AND EXECUTIVE FUNCTIONING IN AN
INCARCERATED SAMPLE

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Marquette University, 2012

Incarcerated adults in the United States represent a significant segment of the population, and traumatic brain injury (TBI) in incarcerated populations has been identified as an area of public health concern. However, not much is known about it because research investigating TBI in incarcerated populations has focused primarily on its relationship to violent behavior. The existing research suggests that a history of TBI may be related to later violent behavior, criminal activity, mental health problems, and poorer institutional and community adjustment. Further, some of the cognitive deficits found in the general population following TBI, including executive dysfunction, have also been found in incarcerated populations. The purpose of the current study was to address a gap in the research by examining the relationship between TBI and executive functioning in a sample of adults incarcerated in the Federal Prison System. The study aimed to describe the neurocognitive functioning of the sample in the domains of IQ, executive functioning, verbal memory, attention, and motor skills. Further, hypotheses based on the theory of cognitive reserve were tested regarding the relationships between TBI, executive functioning, and institution behavior. Overall, the sample demonstrated average performance across the majority of cognitive domains tested. The range of scores in all domains spanned from profound impairment to superior performance. Multivariate analysis of variance was used to look for differences in executive functioning across varying levels of TBI severity, though no significant difference was found. Regression analyses found that lower cognitive reserve was associated with lower executive functioning, though structural equation modeling did not support a relationship between executive functioning and subsequent institutional behavior. Caveats in interpreting test scores, particularly in the domain of executive functioning, are discussed, along with possible explanations for differences in cognitive functioning across incarcerated subgroups. Based on the findings of this study, it is recommended that correctional institutions increase screening and cognitive testing of individuals who present with risk factors for possible executive dysfunction (e.g., history of violent offenses, TBI) in order to better classify the inmate population. Further, individualized treatment and the incorporation of programming that specifically targets executive dysfunction are recommended.

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	i
LIST OF TABLES.....	v
LIST OF FIGURES.....	vii
LIST OF ACRONYMS.....	viii
CHAPTER	
I. INTRODUCTION.....	1
Overview of the Literature.....	1
Statement of the Problem.....	7
Research Questions and Hypotheses.....	8
II. REVIEW OF THE LITERATURE.....	11
Prevalence of Traumatic Brain Injury.....	11
Defining Traumatic Brain Injury.....	14
Implications of Traumatic Brain Injury.....	20
Implications of TBI in Offender Populations.....	29
Summary and Conclusions.....	35
III. METHODS.....	41
Study Participants.....	41
Measures.....	45
Procedures.....	60
IV. RESULTS.....	65
Preliminary Analysis.....	65
Primary Analyses.....	67
V. DISCUSSION.....	100

Summary of Results.....	101
Interpretation of Results.....	105
Limitations.....	110
Implications and Recommendations.....	113
Future Research.....	117
Conclusion.....	118
BIBLIOGRAPHY.....	120

LIST OF TABLES

Table 3.1: Range and Means (Standard Deviations) of Demographic Variables.....	43
Table 3.2: TBI Severity Levels Reported in the Sample.....	43
Table 3.3: Severe Mental Illness and Substance Abuse Diagnoses Within the Sample.....	43
Table 3.4: Measures of Central Tendency for Institutional Behavior Variables.....	44
Table 3.5: Current and Past Criminal Behavior Within the Sample.....	44
Table 4.1: Squared Multiple Correlation (R^2_{smc}) for Each Predictor Variable.....	67
Table 4.2: Range and Means (Standard Deviations) of Test Scores.....	69
Table 4.3: Average Scores on Executive Functioning Measures.....	69
Table 4.4: Measures of Central Tendency for Memory Measures.....	70
Table 4.5: Measures of Central Tendency for Attention and Motor Measures.....	70
Table 4.6: Pearson r Correlations for Measures of Executive Functioning Using T Scores for Trails B and Perseverative Errors.....	71
Table 4.7: Levene's Test of Equality of Error Variances.....	71
Table 4.8: Mean Test Scores by TBI Severity.....	72
Table 4.9: MANOVA – Executive Functioning Measures Between TBI Severity Group Comparison.....	72
Table 4.10: Correlations Between Cognitive Reserve and Executive Functioning Variables.....	74
Table 4.11: Results of Standard Multiple Regression to Predict Trails B (Y) from Education (X_1), IQ (X_2), Number of TBIs (X_3), and Substance Abuse (X_4).....	78
Table 4.12: Results of Standard Multiple Regression to Predict WCST Perseverative Errors (Y) from Education (X_1), IQ (X_2), Number of TBIs (X_3), and Substance Abuse (X_4).....	80

Table 4.13: Results of Standard Multiple Regression to Predict WCST Categories (Y) from Education (X_1), IQ (X_2), Number of TBIs (X_3), and Substance Abuse (X_4).....	82
Table 4.14: Correlations Between Institution Behavior Variables and Executive Functioning Measures.....	83
Table 4.15: Latent Variables and Their Indicators.....	84
Table 4.16: EFA with all Cognitive Reserve and Executive Functioning Variables.....	88
Table 4.17: Goodness-of-Fit Statistics for Confirmatory Factor Analyses.....	93
Table 4.18: Goodness-of-Fit Statistics for Full Structural Equation Model Analyses.....	97
Table 4.19: Standardized and Unstandardized Coefficients for the Measurement Model.....	99
Table 4.20: Standardized and Unstandardized Parameter Estimates for the Structural Model.....	99

LIST OF FIGURES

Figure 1.1: Original Full Structural Equation Model.....	10
Figure 4.1: Trails B Standardized Residuals.....	75
Figure 4.2: WCST Perseverative Errors Standardized Residuals.....	76
Figure 4.3: WCST Categories Completed Standardized Residuals.....	76
Figure 4.4: Cognitive Reserve Measurement Model.....	84
Figure 4.5: Executive Functioning Measurement Model.....	85
Figure 4.6: Institution Behavior Measurement Model.....	85
Figure 4.7: Full Structural Equation Model in MPlus Language.....	86
Figure 4.8: Revised Cognitive Reserve Measurement Model.....	89
Figure 4.9: Revised Executive Functioning Measurement Model.....	90
Figure 4.10: Revised Structural Model.....	94
Figure 4.11: Standardized Results for the Full Structural Equation Model.....	98

LIST OF ACRONYMS

1. ACRM – American Congress of Rehabilitation Medicine
2. AODA – Alcohol and other drug abuse
3. BOP – Federal Bureau of Prisons
4. BPAQ-SF – Buss-Perry Aggression Questionnaire – Short Form
5. BRC – Brain Reserve Capacity
6. CDC – Center for Disease Control and Prevention
7. CES-D – Center for Epidemiologic Studies Depression Scale
8. CHI – Closed head injury
9. CT – Computerized tomography
10. CVLT – California Verbal Learning Test
11. CVLT-II – California Verbal Learning Test – 2nd Edition
12. EEG – Electroencephalogram
13. GAMA – General Ability Measure for Adults
14. GCS – Glasgow Coma Scale
15. HVLT-R – Hopkins Verbal Learning Test – Revised
16. LOC – Loss of consciousness
17. MHPP – Mental Health Prevalence Project
18. MRI – Magnetic resonance imaging
19. NDS – Neuropsychological Dysfunction Scale
20. NRS-R – Neurobehavioral Rating Scale – Revised
21. PAI – Psychological Assessment Inventory

22. PCS – Post-concussive syndrome
23. PDS – Psychology Data System
24. PET – Positron emission tomography
25. PSI-CF – Pre-Sentencing Investigation Coding Form
26. PSIQ – Psychology Services Inmate Questionnaire
27. PTA – Posttraumatic amnesia
28. PTSD – Posttraumatic Stress Disorder
29. SDMT – Symbol Digit Modalities Test
30. SEM – Structural equation modeling
31. SIS – Second impact syndrome
32. TBI – Traumatic brain injury
33. TBIQ – Traumatic Brain Injury Questionnaire
34. TMT – Trail Making Test
35. WCST – Wisconsin Card Sorting Test
36. WCST-64 – Wisconsin Card Sorting Test – 64 Card Version
37. WHO – World Health Organization

CHAPTER ONE INTRODUCTION

Incarcerated adults in the United States represent a significant segment of the population. This group also includes many individuals with significant health needs, including mental health issues in particular. Rates of mental health problems in this group are highly over-represented when compared to the rates found in the general population, with more than half of prison and jail inmates having current symptoms or a recent history of mental health problems (James & Glaze, 2006). The prevalence and implications of traumatic brain injury (TBI) among the nation's incarcerated has also been identified as a public health concern (Center for Disease Control and Prevention (CDC), n.d.), and the limited research available suggests the rates of TBI are very high and the implications are significant. The present study examined the relationship between TBI and executive functioning within a federally incarcerated sample.

Overview of the Literature

Traumatic brain injury impacts a significant number of people in the United States across all age groups and social classes. Certain demographic groups, however, are at higher risk, including children and young adults, males, those from lower socioeconomic and education levels, and the unemployed (Thurman et al., 1999; Hannay, Howieson, Loring, Fischer, & Lezak, 2004). The Center for Disease Control and Prevention (CDC) estimated that over five million children and adults in the United States are living with permanent TBI-related disabilities, leading to societal, financial, and human costs of TBI. To address this public health concern, Congress mandated the CDC to develop methods for consistently tracking TBI, prevention measures, and to report the incidence and

prevalence of TBI (Thurman et al., 1999. p.4-5). These measures helped to improve tracking methods in medical settings and increased our knowledge of the scope of TBI among individuals who receive medical care for their injuries. However, determining the cost and consequence of TBI in populations outside the hospital setting is more problematic.

The rate of TBI among incarcerated populations is of special concern. Though there is no uniform tracking or screening system in place at the federal or state level, rates of TBI in correctional populations are estimated to be far higher than those found in the general population (CDC, n.d.; Diamond, Harzke, Magaletta, Cummins & Frankowski, 2007). The rate and implications of TBI in incarcerated samples is a small and growing area of research, much of which indicates that TBI should be an area of concern. Most studies have identified rates of TBI in their samples that are much higher than what is found in the general population, though many methodological issues—such as small samples or representativeness of samples—make the existing research difficult to generalize (Diamond, Wang, Holzer III, Thomas, & Cruser, 2001). Further, the research suggests incarcerated individuals with TBI have poorer institutional and community outcomes than those with no history of TBI (Bryant, Scott, Golden & Tori, 1984; Rosenbaum et al., 1994; Merbitz, Jain, Good, & Jain, 1995).

Efforts by the CDC, the World Health Organization (WHO), and other major organizations have led to the development of more standardized methods for defining TBI and its three severity levels: mild, moderate, and severe (Thurman, Sniezek, Johnson, Greenspan, & Smith, 1995; Borg et al., 2004). However, not all TBI research has consistently used these definitions, and the true rate of TBI and the scope of its

consequences remain unknown (CDC, 2006). In particular, mild TBI, which is believed to account for at least 75 percent of all TBIs in the United States, is hardest to consistently track, in part because mild TBI cases often receive less or no medical treatment (National Center for Injury Prevention and Control, 2003). Further, the implications of mild TBI are a controversial topic in the research literature, which also makes it difficult to determine the true scope of the costs and consequences of mild TBI as well as TBI in general.

Neuro-imaging techniques such as positron emission tomography (PET) and magnetic resonance imaging (MRI) have shown that the structural neuropathology often seen following moderate and severe TBI is not always evident with mild TBI. This leads some to question whether mild TBI actually causes lasting damage to the brain, or if TBI is the true cause of the symptoms individuals report following such injuries (Koch, Merz, & Torkelson Lynch, 1995). The ongoing debate is fueled by the heterogeneous nature of the neuropathology and symptoms seen across individuals following an incident of TBI of all severity levels (Stuss & Gow, 1992). Individuals who experience a TBI can develop physical, cognitive, behavioral, or emotional changes and deficits following the injury. Most individuals experience problems in more than one area, and it is possible for two people with very similar injuries to present with different symptoms and have different short- and long-term outcomes following their injury (Lezak, Howieson, & Loring, 2004).

This heterogeneity of effects can be related to pre-morbid factors such as a history of substance abuse or neurological problems (National Center for Injury Prevention and Control, 2003), and to the diffuse nature of the damage to the brain that is typical of TBI

(Stuss & Gow, 1992). Further, the systemic nature of brain functioning and of cognitive processes mean that functions can be interrupted by damage to many different parts of the brain. For example, the frontal lobes of the brain are at high risk of being damaged following TBI because of their proximity to bony protrusions in the skull (Stuss & Gow, 1992), and damage to this area is often implicated in many of the deficits seen following TBI (Lezak et al., 2004). The frontal lobes are responsible for many higher-level cognitive processes including executive functions, such as organizing information and response inhibition, and their role in numerous cognitive processes creates reciprocal connections with many other brain structures (Lezak et al., 2004; Mesulam, 2000; Luria, 1973).

There are a variety of cognitive impairments related to TBI. Impairment of executive functioning has been found following injuries of all severity levels (Stuss & Gow, 1992; Spikman, Deelman, & van Zomeren, 2000). Other cognitive impairments such as memory deficits, attention problems, and processing speed deficits can also be seen following a brain injury (Hannay et al., 2004). These deficits can be short- or long-term and are thought to be influenced by several factors, including age at injury, pre-morbid IQ, and the level of education attained by the individual (Lezak et al., 2004). Satz (1993) proposed a theory of cognitive reserve as a possible explanation for this heterogeneity of cognitive changes seen following TBI, and subsequent research has shown support for the theory (Ropacki & Elias, 2003; Kesler, Adams, Blasey, & Bigler, 2003).

Cognitive reserve theory describes how individuals with a higher level of cognitive reserve are better protected against the damage caused by a head trauma and are

better equipped to recover from the sequelae of TBI; individuals with a lower level of cognitive reserve experience just the opposite (Stern, 2002). Cognitive reserve levels are related to general intelligence and education and occupation levels. The greater the amount of neurological deficits a person has (e.g. chronic substance abuse, repeat brain injury, psychiatric problems), the lower their cognitive reserve level (Ropacki & Elias, 2003; Satz, 1993).

Along with cognitive changes, many people experience physical symptoms and behavioral changes following TBI. Headaches, nausea, seizures, and balance problems can all occur following TBI and can be short lived or long term (Koch et al., 1995). Behavioral deficits—often related to the executive dysfunction described above—include impulsivity and lack of inhibition, as well as aggressive and violent behavior (Filley et al., 2001; Kim, 2002). These changes can have a significant impact on the individual's interpersonal relationships and their ability to return to work. A number of different affective disturbances can also occur following TBI and can further interfere with the individual's interpersonal interactions and social functioning.

Irritability, anger, paranoia, and anhedonia may occur post-injury, along with profound changes in personality (Prigatano, 1992; Kim, 2002). Individuals with TBI are at greater risk of developing depression, even decades after their injury (Holtzer, Burright, Lynn, & Donovan, 2000; Holsinger et al., 2002). TBI can also increase an individual's risk for several other psychiatric disorders, including psychotic disorders and post-traumatic stress disorder (PTSD), as well as substance abuse and suicide risk (Silver, Kramer, Greenwald, & Weissman, 2001; Kim et al., 2007). A lack of self-awareness regarding changes in their cognitive abilities, emotions, and behaviors often accompanies

these disturbances, which can interfere with rehabilitation efforts (O’Keeffe, Dockree, Moloney, Carton, & Robertson, 2007).

All of these cognitive, behavioral, and emotional changes can affect an individual’s recovery of function and community re-integration following TBI. Research has shown that long-term deficits do interfere with how individuals manage their tasks of daily living and social functioning, particularly among individuals with moderate and severe TBI (Colantonio et al., 2004). TBI research in incarcerated populations has also identified difficulties with community re-integration, as the vast majority of research in this area has looked at criminal and violent behavior (both pre- and post-injury) and its potential relationship to TBI. There are likely several reasons for the focus on links between TBI and antisocial behaviors, such as community safety and policy implications. Additionally, TBI research in corrections is qualitatively different than that done in the community, since community research typically involves individuals with a known incident of TBI who become involved with medical care. In contrast, incarcerated samples typically consist of individuals who report one or more instances of TBI in their lifetime, and the injury often occurred long before the research was conducted.

As a result of community safety and policy concerns, several research studies have examined the relationship between TBI and later violent behavior and suggested there is an increase in violent behavior among individuals with TBI (Leon-Carrion & Ramos, 2003; Rosenbaum et al., 1994; Marsh & Martinovich, 2006). However, far less research has examined other cognitive and emotional sequelae of TBI among incarcerated adults, though emotional adjustment problems and mental health issues have been found to be more prevalent among those with TBI (Sarapata, Herrmann, Johnson,

Aycock, 1998; Schofield et al., 2006). A number of sequelae beyond an increase in violent behavior have been found among justice-involved individuals with TBI: executive dysfunction (Marsh & Martinovich, 2006); generally poorer cognitive functioning (Sarapata et al., 1998); institutional adjustment problems (Merbitz et al., 1995); and a higher level of risk upon return to the community (Hawley & Maden, 2003).

Taken together, the research in both community and correctional settings indicates that TBI is a significant problem with a variety of serious implications. The costs to both individuals who experience TBI and to society are great, due to the high number of individuals impacted by TBI and the long-term nature of some of the deficits associated with it. Individuals can experience changes in cognition, behavior, and emotion that can interfere with their interpersonal interactions and ability to function in society. For those with a history of TBI who are incarcerated, these changes can lead to problems adjusting to life in an institution and struggles with adjusting to life in the community upon their release.

Statement of the Problem

In summary, TBI in incarcerated populations has been identified as an area of public health concern, though not much is known about it. The existing research suggests that a history of TBI may be related to later violent behavior, criminal activity, mental health problems, and poorer institutional and community adjustment. Further, some of the cognitive deficits found in the general population following TBI, including executive dysfunction, have also been found in incarcerated populations. TBI research conducted in the community has investigated and identified the cognitive, emotional, behavioral, and social sequelae following mild, moderate, and severe TBI. In contrast, research

investigating TBI in incarcerated populations has focused almost exclusively on its relationship to violent behavior. A number of studies have examined the neuropsychological functioning of select groups of offenders, such as those on death row (Lewis, Pincus, Feldman, Jackson, & Bard, 1986; Hanlon, Rubin, Jensen, & Daoust, 2010) and those identified as psychopaths (Pham, Vanderstukken, Philippot, & Vanderlinden, 2003), while others have looked for relationships between neuropsychological functioning and antisocial behaviors (Cohen, Rosenbaum, Kane, Wamken, & Benjamin, 1999; Morgan & Lilienfeld, 2000).

Very little research has looked specifically at neuropsychological functioning in justice-involved individuals with a history of TBI (Barnfield & Leathem, 1998b; Slaughter, Fann & Ehde, 2003) or at executive functioning and TBI (Marsh & Martinovich, 2006). The current study attempted to address this gap in the research by examining the neuropsychological functioning—and specifically the executive functioning—as it related to TBI in a sample of adults incarcerated in the Federal Prison System.

Research Questions and Hypotheses

The current study used archival data gathered from a sample of 225 adult men and women incarcerated by the Federal Bureau of Prisons (BOP). The data included demographics, prior mental health and substance abuse issues, criminal history, self-reported history of head injury incidence and severity, mental health symptoms, and the number of behavioral infractions incurred during the current incarceration. Neuropsychological test data included the General Ability Measure for Adults, the Hopkins Verbal Learning Test – Revised, the Wisconsin Card Sorting Test – 64, the Trail

Making Test, the Symbol Digit Modalities Test, and the Grooved Pegboard. Using these data, the following research question and hypotheses, which were based on the theory of cognitive reserve, were addressed.

Research Questions:

1. What is the level of neurocognitive functioning in the domains of IQ, executive functioning, verbal memory, attention, and motor skills for this sample?

Hypotheses:

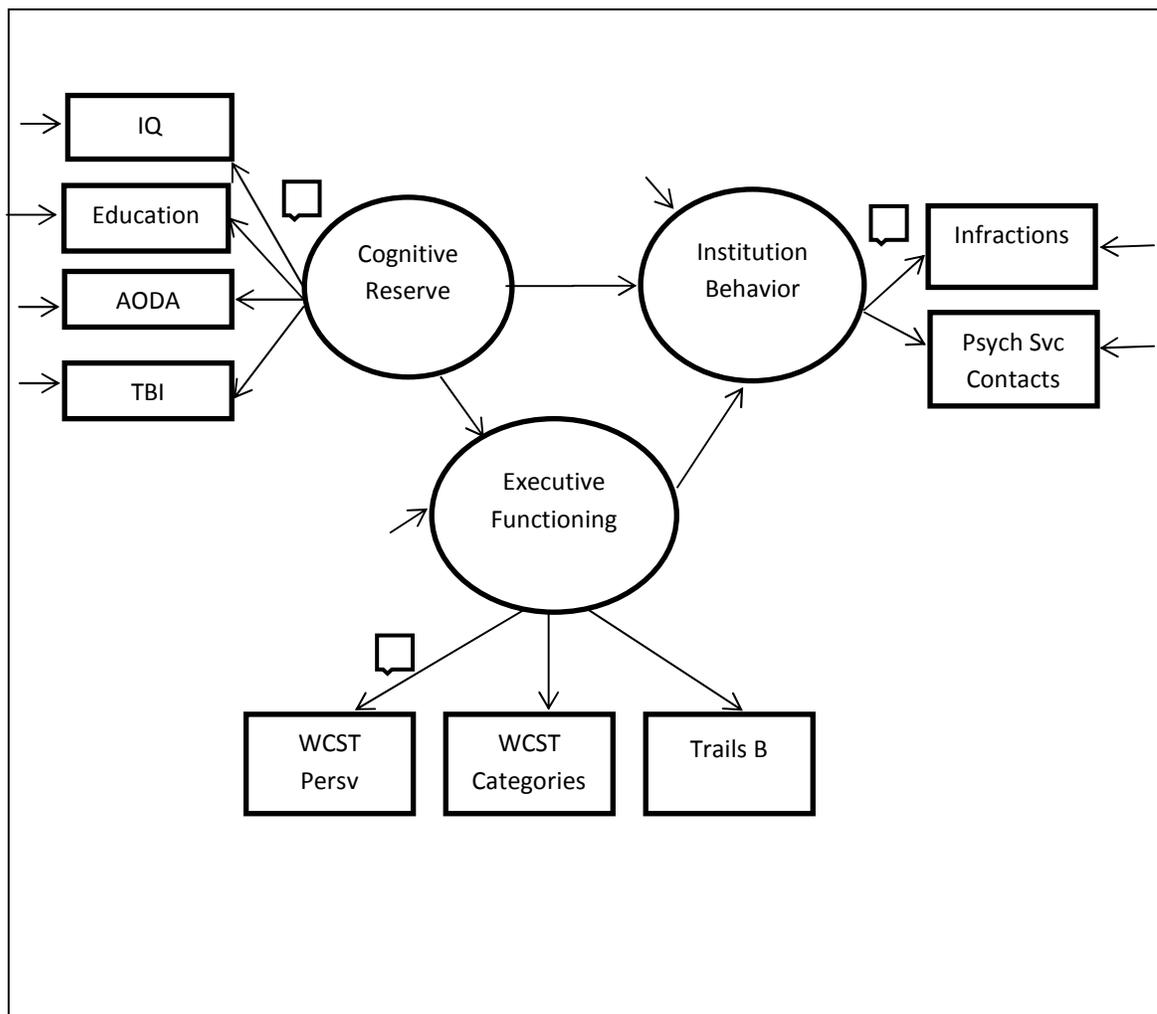
2. Individuals reporting more severe head injuries (moderate, severe) will show greater deficits in executive functioning than those reporting mild head injuries or no head injuries.
3. Individuals with lower cognitive reserve (i.e., substance abuse history, history of TBI, lower IQ, lower educational attainment) will show greater deficits in executive functioning than those with higher cognitive reserve.
4. Individuals with greater executive functioning deficits will exhibit more behavior problems during the first two years of the current incarceration.

Additionally, structural equation modeling was used to test the cognitive reserve theory and explore the relationships between cognitive reserve, executive functioning, and behavior in the institution. The following three relationships were posited in the original conceptual model presented below (Figure 1.1):

1. Cognitive reserve and executive functioning will be correlated, and greater cognitive reserve will be positively related to greater executive functioning.
2. Greater cognitive reserve will be positively related to better institutional behavior (i.e., fewer behavioral infractions and psychological services contacts).

- Executive functioning will mediate the relationship between cognitive reserve and institutional behavior.

Figure 1.1 Original full structural equation model



CHAPTER TWO REVIEW OF THE LITERATURE

The following section will summarize the traumatic brain injury (TBI) research literature beginning with the prevalence of TBI in the United States and in incarcerated populations. Following this will be a description of how TBI is defined, the known implications of TBI, and the unique implications of TBI in correctional settings.

Prevalence of Traumatic Brain Injury

Prevalence in the United States

Traumatic brain injury (TBI) is a significant problem in the United States. The Center for Disease Control (CDC) estimates that at least 1.4 million people sustain a TBI each year (Langlois, Rutland-Brown & Thomas, 2006). Brain injuries are more likely to result in death than any other type of injury, and TBI is the leading cause of long-term disability both in the United States and worldwide (North American Brain Injury Society, n.d.; Thurman et al., 1999) making TBI a significant public health concern. It is the primary cause of brain damage in children and young adults, and individuals between the ages 15 and 24 are one of the highest risk groups for sustaining a TBI (Thurman et al., 1999). In addition to age, other factors such as socioeconomic status, unemployment, and lower educational attainment have been described as risk factors for TBI (Hannay et al., 2004).

Prevalence in Incarcerated Populations

Individuals incarcerated in the United States represent a significant segment of the population. According to the U.S. Department of Justice, over 2 million adults were incarcerated in state and federal prisons and over five million were under community

supervision through probation or parole at year-end 2009 (Glaze, 2010). The health status of this segment of the population has been identified as a concern because mental health problems are significantly overrepresented in incarcerated adults. According to the U.S. Department of Justice, “at midyear 2005 more than half of all prison and jail inmates had a mental health problem” (i.e., state prisoners, federal jail inmates, and federal prisoners combined; James & Glaze, 2006, p.1). Relatively little is known about the number of inmates and prisoners with TBI, however. As TBI and its impact have become a greater public health concern in the United States, they have also been identified as an important health problem among the nation’s incarcerated (CDC, n.d.).

To date, the majority of studies appear to indicate the rate of TBI may be significantly higher than that found in the general population (Magaletta, Diamond, Dietz, & Jahnke, 2006; Colantonio, Stamenova, Abramowitz, Clarke, & Christensen, 2007). Among research studies with relatively small samples, rates of TBI have ranged from 8% for a group of 13 non-violent offenders (Leon-Carrion & Ramos, 2003) up to 100% for a sample of 15 inmates on death row (Lewis et al., 1986). Studies with much larger samples have also shown high rates, with 88% of a sample of 225 offenders (Diamond et al., 2007) and 82% of a sample of 200 offenders (Schofield et al., 2006) reporting a history of TBI. Another study that screened 1000 consecutively admitted offenders to a state prison found that 24.9% reported a history of at least one TBI (Morrell, Merbitz, Jain, & Jain, 1998). More recently, a meta-analysis was conducted that included data from 20 studies, including many of those described above, and estimated a TBI prevalence rate of 60.25% for the sample of 4,865 offenders (Shiroma, Ferguson, & Pickelsimer, 2010).

Some researchers have attempted to identify reasons why rates of head injury, and therefore rates of TBI, may be higher in incarcerated populations. In a review of this literature, Raine (1993) described several explanations that link criminal activity with head injury. One explanation posited that involvement in violence and crime is a risk factor for head injury. Another explanation suggested that there are common demographic factors associated with both head injury and crime including living in an inner city and being young, male, or of minority status. For example, head injury is 1.5 times more likely to affect men than women (CDC, 2006) and over 90% of federal and state offenders are male (Bureau of Justice Statistics (a), n.d.). Additionally, African American males have the highest incarceration rate in proportion to their overall representation in the general population, and the majority of state and federal prisoners are under the age of 25 (Bureau of Justice Statistics (a), n.d.). These numbers coincide with data indicating African Americans between the ages of 15 and 44 have higher rates of TBI-related emergency room visits and hospitalizations (CDC, 2006).

Though the causes of the elevated TBI rate among incarcerated adults are not well understood, the evidence presented thus far clearly suggests that rates of TBI are significant in correctional populations. Knowledge and awareness of the incidence of TBI in the general population has increased over time as it has become a focus for research (Langlois et al., 2006). However, only one large-scale meta-analysis to date has attempted to determine the incidence of TBI among incarcerated populations. Further, a variety of limitations in the existing research have made it difficult to develop reliable estimates of the prevalence of TBI and other mental impairments in incarcerated populations. These include problems with representativeness of samples, small sample

sizes, and lack of consideration for comorbidities between neuropsychological impairment and mental illnesses (Diamond et al., 2001). In addition, one of the greatest barriers to studying TBI and its impact on both the general population and the incarcerated is the issue of how TBI is defined.

Defining Traumatic Brain Injury

Despite its negative impacts on individuals and on society, TBI is often referred to as a silent epidemic for reasons such as limited public awareness and lack of clarity regarding its consequences (Langlois et al., 2006). Additionally, multiple definitions exist for traumatic brain injury, and there are alternate terms (e.g., head injury, traumatic brain injury) that are used synonymously in TBI research. There are also varying definitions used to describe the severity of traumatic brain injury (commonly referred to as mild, moderate, and severe). All these factors make it difficult to generalize the results of the available research on TBI.

Despite the lack of consensus on definitional issues, there are common factors that are typically addressed in TBI definitions including loss of consciousness (LOC), memory loss for events surrounding the trauma (post-traumatic amnesia or PTA), alteration of mental state at the time of trauma, and the absence or presence of focal neurological damage (Murrey, 2008). To clarify, posttraumatic amnesia can be defined as “the loss of memory for events immediately before or after the accident... typically includ[ing] an inability or reduced ability to effectively process information or stimuli (visual or otherwise) post-injury” (Murrey, 2008, p.3). Alteration in mental status typically consists of a sense of confusion or disorientation following the injury. In addition to being used for the identification of TBI, the factors just described are also

used to distinguish between the different levels of severity. The ability to classify TBI is important for several reasons. For example, use of initial severity of injury as a primary indicator of prognosis, which is consequently important for determining the level of care needed and estimating the likelihood of risks and complications (van Baalen et al., 2003).

Loss of consciousness is one of the primary ways that TBI severity level has been classified. The Glasgow Coma Scale (GCS; National Center for Injury Prevention and Control, 2003) is the most common assessment for the level of consciousness a person exhibits shortly after a head injury occurs. The GCS “formally and objectively assesses eye, motor, and verbal responses to various external stimuli” (Murrey, 2008, p.2) and gives a total score between 3 and 15. Scores of 8 or less are considered severe, 9 to 12 are considered moderate, and 13 to 15 are considered mild in terms of injury severity (National Center for Injury Prevention and Control, 2003, p.7). Similarly, PTA is also used to indicate severity of injury, with PTA lasting less than one hour indicating mild injury (Gronwall, 1991) and 24 hours or longer indicating severe injury (National Center for Injury Prevention and Control, 2003). Finally, penetration or compromise of the skull is clear evidence of focal neurological damage and qualifies as severe injury.

The presence of physical damage to the brain is another way TBI is diagnosed in medical settings, and it is more readily seen in moderate and severe TBI. There has been debate in the literature as to whether or not mild TBI results in physical damage to the brain such that abnormalities in clinical neuro-imaging (e.g. computerized tomography (CT), magnetic resonance imaging (MRI), or positron emission tomography (PET) scans) can be found. A review of the literature in this area, however, found that individuals with mild TBI (GCS of 15) showed abnormalities in CT scans only about 10% of the time, and

this number increased to 20% or more with GCS scores of 13-14 (Arciniegas, Anderson, Topkoff, & McAllister, 2005). Further, some research has found electroencephalogram (EEG) to be capable of discriminating between mild and severe TBI (Thatcher et al., 2001), suggesting that mild TBI can result in neurobiological changes.

The Center for Disease Control has provided the following frequently cited definition for traumatic brain injury that incorporates several of the TBI indicators just described. It reads as follows.

A case of traumatic brain injury is defined as either an occurrence of injury to the head that is documented in a medical record with one or more of the following conditions attributed to head injury:

- Observed or self-reported decreased level of consciousness
- Amnesia
- Skull fracture
- Objective neurological or neuropsychological abnormality
- Diagnosed intracranial lesion

Or as an occurrence of death resulting from trauma, with head injury listed on the death certificate, autopsy report, or medical examiner's report in the sequence of conditions that resulted in death. (Thurman et al., 1995, p. I-7)

This definition was designed to identify TBI that results in hospitalization, making it more applicable to moderate and severe brain injury (National Center for Injury Prevention and Control, 2003).

There is more variability in the literature with regard to defining mild traumatic brain injury and its incidence and outcomes than there is for moderate or severe brain injury. Several different organizations have promulgated definitions in an effort to establish a more uniform definition of mild TBI. The earliest and most often cited definition was developed by the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine (ACRM). Their definition reads as follows.

A patient with mild traumatic brain injury is a person who has had a traumatically induced physiological disruption of brain function, as manifested by at least one of the following:

- Any period of loss of consciousness;
- Any loss of memory for events immediately before or after the accident;
- Any alteration in mental state at the time of the accident (e.g. feeling dazed, disoriented, or confused); and
- Focal neurological deficit(s) that may or may not be transient;

But when the severity of the injury does not exceed the following:

- Loss of consciousness of approximately 30 minutes or less;
- After 30 minutes [post-injury], an initial Glasgow Coma Scale (GCS) of 13-15; and
- Posttraumatic Amnesia (PTA) not greater than 24 hours. (American Congress of Rehabilitation Medicine, 1993, p.86)

Additionally, the ACRM states that in situations where some of the above factors are not medically documented (e.g., GCS scores), one can consider long-term symptomatology that may suggest the existence of mild TBI following a head injury (e.g. persistent emotional, cognitive, behavioral, and physical symptoms). The CDC also developed a definition of mild TBI that is essentially the same as the ACRM definition with the exception that the CDC does not directly describe PTA as needing to be less than 24 hours (National Center for Injury Prevention and Control, 2003).

A third definition for mild TBI was developed by The World Health Organization (WHO) Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury. This task force conducted a review and critical analysis of the literature on mild TBI regarding epidemiology, diagnosis, prognosis, and treatment, and developed a definition based on that analysis (Borg et al., 2004; Holm, Cassidy, Carroll, & Borg, 2005). It contains all the same elements as the ACRM definition described above. Consistency across these definitions of mild TBI is important because they have all been

used to define mild TBI in research studies. However, many studies do not use one of these three definitions, nor do they clearly describe the criteria used to define mild TBI.

Another complicating factor with regard to defining mild TBI is the variety of terms used to describe mild TBI and its symptoms including such terms as concussion, minor head injury, minor brain injury, minor head trauma, and post-concussion syndrome (Arciniegas et al., 2005; National Center for Injury Prevention and Control, 2003). The term concussion is used most often when describing sports-related closed head injuries. Its defining features, as described in the sports literature, are essentially the same as those described above for mild TBI. The severity of concussion is judged according to loss of consciousness and its duration, PTA, alteration in reflexes, and post-trauma physical and cognitive symptoms (Webbe, 2006).

Arciniegas and his/her colleagues (2005) argued that post-concussive syndrome (PCS) describes problems that result from mild TBI (including cognitive, physical, and emotional/behavioral) and should be considered a distinct concept. In the sports and forensic literatures, PCS is treated as a distinct concept described as a specific diagnostic formulation with several associated symptoms including fatigue, irritability, depression, difficulties with attention and concentration, confusion, social withdrawal, apathy, dizziness, headaches, nausea, sleep difficulties, and sensitivity to noise that persist well beyond the date of injury (Patch & Hartlage, 2003). It is also inappropriate to use terms such as minor head injury or minor head trauma interchangeably with the term mild TBI because not all head injuries produce brain damage or cognitive impairment. Nonetheless, the term *head injury* appears quite often in research looking at TBI, most

often in studies using self-report data, and will be used in the current review when describing studies that used the term.

The variety of terms and criteria used to describe mild TBI creates difficulties in generalizing from the research on the subject. To help avoid this problem, the CDC, ACRM, and WHO definitions described above were each developed in an effort to identify mild TBI more consistently. Another factor driving the need for clearer definitions of mild TBI is that this level of TBI is the most common type seen in hospitals (i.e., 70-90% of all cases). When untreated mild TBI is included, the annual rate of TBI is estimated to be approximately 600/100,000 in the U.S. population (Holm et al., 2005, p.137). Another driving factor is the lack of clarity regarding the symptoms and deficits that follow mild TBI. There has been significant debate in the research regarding the self-reported symptoms following mild TBI with some researchers questioning their validity and true etiology (Gordon et al., 1998). The physical damage to the brain that is often found following moderate and severe TBI is generally believed to be lacking in mild TBI, and this lack of objective data to support the subjective complaints reported by individuals following a mild TBI has been viewed as problematic (Koch et al., 1995).

There is general consensus that symptoms following mild TBI resolve within the first three months for the majority of individuals. The findings of one meta-analysis support this view for the mild cognitive impairments that often follow mild TBI (Frencham, Fox, & Maybery, 2005). However, the remainder of individuals with mild TBI can go on to develop “persistent cognitive, emotional, behavioral, and physical impairments that extend well into the late (>1 year) period following TBI” (Arciniegas et al., 2005, p. 312). This is referred to as post-concussion syndrome (PCS). Whether these

longer term symptoms are a direct result of the mild TBI or are related to other pre-morbid factors has been debated in the literature, though most research seems to suggest that the incidence of PCS is likely 5% or fewer of the cases (McCrea, 2011). Unlike mild TBI, the research regarding impairments following moderate and severe TBI tends to find that many of the symptoms following moderate and severe TBI persist as long-term disabilities.

Implications of Traumatic Brain Injury

Traumatic brain injuries can result in functional deficits in a variety of areas including physical, behavioral, cognitive, and emotional changes, and it is not uncommon for individuals with similar types of injuries to have different symptom presentations following injury. A TBI can be caused by an injury in which the skull is penetrated or by a closed head injury (CHI). CHIs are the most common cause of damage to the brain and different factors can cause damage either at the time of impact or some point thereafter. In the past, injuries related to CHI were classified as either primary or secondary depending on their proximity to the time of injury. The first injuries (formerly called primary injury) occur at the time of impact and relate to inertial forces of the impact causing the brain to move within the skull and be damaged by its bony structures. Other injuries can occur later (formerly called secondary injury) and are caused by physiological processes that can follow an injury including swelling of the brain, hypoxia, fever, and infection (Hannay et al., 2004).

The type and amount of damage sustained have an impact on the severity of deficits that present following the injury, though no direct relationship has been shown between the degree of brain pathology caused by an injury and the level of dysfunction

that follows (Stern, 2002). Some researchers have suggested that the severity of deficits and outcomes following a TBI are complicated by and sometimes mistaken for pre-morbid factors such as substance abuse, neuropsychiatric history, and age. Research findings regarding this issue have been inconsistent (National Center for Injury Prevention and Control, 2003). Theories of brain and cognitive reserve have been developed as a way to explain the individual differences in recovery of function that are often seen after TBI (Stern, 2002).

Brain reserve and cognitive reserve are theoretical constructs that are believed to play a role in how the brain reacts to and recovers from an injury, such that higher reserve levels can act as a protective factor from the development of the remote sequelae of brain injury, and lower levels would be a risk factor (Stern, 2002). Brain reserve is a passive reserve believed to derive from the physical size of the brain: a larger brain volume or higher neuronal count would represent greater brain reserve (Richards, Sacker, and Deary, 2007). In contrast, cognitive reserve is viewed as an active process by which the brain copes with damage through neural reserves and neural compensatory approaches. Neural reserves are pre-existing cognitive processes that are efficient and effective enough to withstand disruptions by brain damage, and neural compensation is the development of new cognitive processes to work around significant disruptions caused by brain damage (Stern, 2007).

According to cognitive reserve theory, those with less cognitive reserve are more likely to demonstrate deficits following injuries, and those with pre-morbid neurological deficits (e.g., history of chronic substance abuse, prior brain injury, ADHD, psychiatric problems) have less cognitive reserve. An individual's cognitive reserve can be indirectly

measured via general intelligence, educational level, and occupational level, with lower levels indicating less cognitive reserve and greater vulnerability to longer-term consequences and deficits (Ropacki & Elias, 2003). Brickman, Siedlecki, and Stern (2010) recommend that cognitive reserve be estimated by a summary measure that incorporates multiple experiences and abilities (e.g. educational attainment, occupational attainment, social interactions). In terms of brain reserve, Satz (1993) developed a threshold theory of brain reserve which revolves around the concept of brain reserve capacity (BRC). According to this theory, each individual's BRC is based on the size of their brain. Clinical and functional deficits will follow a brain injury only if the individual's BRC drops below a certain threshold as a result of the injury (Stern, 2007).

Empirical support has been found for both brain reserve and cognitive reserve, though cognitive reserve has been more consistently supported by research. Staff, Murray, Deary, and Whalley (2004) examined both brain and cognitive reserve in a sample of older adults and found support for the cognitive reserve hypothesis but not the brain reserve hypothesis. In contrast, Mortimer, Snowdon and Markesbery (2003) found that either a higher level of educational attainment (cognitive reserve) or increased head size (brain reserve) protected for dementia relative to lower levels. Multiple studies have tested the cognitive reserve theory as it relates to age-related cognitive decline and the development of Alzheimer's disease and have demonstrated a relationship between pre-morbid educational attainment and age-related memory decline (Manly, Touradji, Tang & Stern, 2003; Staff et al., 2004; Ardila, Ostrosky-Solis, Rosselli, & Gomez, 2000). Research has also demonstrated relationships between later cognitive decline and pre-morbid intellectual ability (Alexander et al., 1997; Richards & Sacker, 2003) and

occupational attainment (Staff et al., 2004). Siedlecki and colleagues (2009) tested the validity of cognitive reserve as a distinct construct and found strong convergent validity and moderate discriminant validity. They also found cognitive reserve to be strongly related to executive functioning.

Several studies have also supported the potential moderating effect of cognitive reserve on outcomes following pediatric brain injury (Farmer et al., 2002; Dennis, Yeates, Taylor, & Fletcher, 2007; Fay et al., 2010). Ropacki and Elias (2003) tested the cognitive reserve theory by comparing neuropsychological test performance following closed-head injury in a group of adults with pre-morbid neurological deficits (i.e., substance abuse, psychiatric history, and/or prior neurologic insult) to that of a group without pre-morbid deficits. The groups did not differ significantly in prior education, occupational attainment, pre-morbid IQ, age, or injury severity, though the group with pre-morbid deficits did show a greater decline in cognitive functioning following their injury. Kesler and colleagues (2003) explored the brain reserve hypothesis in a sample of adults with TBI and found that greater premorbid brain size (as measured by total intracranial volume) was protective against a drop in intellectual functioning post-injury. Overall, the literature tends to support the role of cognitive and brain reserve in explaining the heterogeneity of outcomes following TBI, though more research is needed.

Another contributing factor to the heterogeneity in symptoms and outcomes following TBI is the systemic nature of brain functioning. In his theory of brain functioning, Luria (1973) described how human mental processes are “complex functional systems” (p. 43) that result from various structures of the brain working together. The involvement of multiple brain structures means that a cognitive process can

be interrupted by a lesion or insult happening to any of the structures involved. Further, the symptom presentation can be different depending on what part of the system has been damaged.

The pre-frontal region of the brain (or the frontal lobes) is often implicated in the deficits that follow TBI because of the role it plays in many cognitive functions and because of the susceptibility of this region to damage in the event of a TBI (Lezak et al., 2004). The frontal lobes play a large role in many higher order cognitive functions that are often classified as executive functions. They also have reciprocal relationships with many other brain regions and systems (e.g., sensory system, limbic-memory system) and thus play a part in many of the functional systems that underlie cognitive processes (Lezak et al., 2004; Luria, 1973; Mesulam, 2000). As a result, damage to the frontal lobes can impact many cognitive and social behaviors, and can disrupt the reciprocal relationships between the major functional systems involving the frontal lobes (Luria, 1976; Lezak et al., 2004). Loring (1999) defines executive functions as:

Cognitive abilities necessary for complex goal-directed behavior and adaptation to a range of environmental changes and demands. Executive function includes the ability to plan and anticipate outcomes (cognitive flexibility) and to direct attentional resources to meet the demands of nonroutine events. (p. 64)

Lezak and colleagues (2004) describe the four separate components of executive functioning as volition, planning, purposive action, and effective performance. Volition is described as “the capacity for intentional behavior” (p. 612) and has several components including motivation and self-awareness. Planning is the “identification and organization of the steps and elements... needed to carry out an intention” (p. 614) and involves skills such as being able to weigh options and impulse control. Purposive action is the

behaviors of initiating, maintaining, switching, and stopping in order to carry out the plan. Self-regulation is necessary to oversee the entire process and make sure the plan is implemented successfully.

Impaired executive functioning is a common cognitive impairment found after a TBI of any severity level (Leininger, Gramling, Farrell, Kreutzer, & Peck, 1990; Stuss & Gow, 1992; Spikman et al., 2000; Hannay et al., 2004). In a recent meta-analysis, Belanger, Spiegel, and Vanderploeg (2010) found poorer performance on executive functioning tasks among individuals reporting a history of multiple mild TBIs when compared to individuals with one mild TBI. This suggests that recurrent injuries can have a cumulative effect on the brain. Impairments in executive functioning also contribute to many of the behavioral, emotional, and social functioning problems often seen after TBI.

A number of other cognitive impairments in addition to executive dysfunction can be seen after a TBI including deficits in memory and attention (Hannay et al., 2004). Mild cognitive impairment has often been found following mild TBI, with a recent meta-analysis indicating that significant effects on attention and concentration are the most commonly reported cognitive impairments. As described above, these impairments typically resolve within the first three months post-injury (Frenchem et al., 2005). Attentional and processing speed deficits are a common problem for individuals with severe TBI, including problems with dividing and focusing attention (Stuss et al., 1989; Hannay et al., 2004).

In an extensive review of the literature regarding long-term memory impairment following moderate to severe TBI, Vakil (2005) described memory impairment as one of the most significant residual deficits as well as one of the cognitive functions that is

slowest to recover following TBI. The review also found a high degree of heterogeneity across patient groups, indicating a number of different types of memory impairment can follow a TBI. In general, memory impairments following moderate to severe TBI are a common complaint, and multiple aspects of memory can be affected by a brain injury (e.g., implicit, explicit; Hannay et al., 2004; Vakil, 2005).

Physical symptoms are often the first seen following a TBI of any severity level. Acute physical symptoms typically include headaches, dizziness, nausea and vomiting, seizures, and problems with coordination (Koch et al., 1995). These symptoms may be short-lived but may also persist beyond the acute phase of injury (De Kruijk, Twijnstra, & Leffers, 2001). A number of behavioral problems can also follow TBI including impatience, impulsivity, and lack of inhibition. These changes can be the result of frontal lobe damage and can lead to difficulty with interpersonal relationships (Koch et al., 1995). One of the most common behavioral changes associated with TBI is an increased risk for violence and aggression, both acutely following injury and over the long-term (Filley et al., 2001; Dinn, Gansler, Moczynski, & Fulwiler, 2009). In a study comparing 89 patients with TBI (including all three severity levels, though primarily moderate and severe TBI) to 26 control patients, posttraumatic aggression was found significantly more often in the TBI group during the first six months following injury (Tateno, Jorge, & Robinson, 2003).

Another study comparing Vietnam veterans with penetrating head wounds to a matched control sample of non-head-injured veterans also found significantly higher rates of aggression in those with head injury. In particular, those with focal frontal lobe lesions showed the highest levels of violent and/or aggressive behavior (Grafman et al., 1996).

Further, in a review of the literature regarding agitation and aggression following TBI, Kim (2002) described high rates of agitation during the acute recovery period prior to the resolution of PTA. Beyond the acute recovery stage, agitation also continued to be exhibited in a large percentage of those cases with severe TBI.

In addition to irritability and agitation, a variety of other affective disturbances have also been seen following TBI such as anger, emotional lability, paranoia, and anhedonia (Prigatano, 1992). Depression has been repeatedly found to be a complication of brain injuries at all severity levels. A review of literature from 1978 to 2006 estimated that 15.6% to 60% of individuals met criteria for major depressive disorder following brain injury (Kim et al., 2007). Depression has been found in the months immediately following TBI among all injury severity levels (Holtzer et al., 2000). A study of 520 World War II veterans who had experienced severe head injury compared to 1198 veterans who had not found that veterans with head injury more often reported current and past depression and that their risk for depression remained elevated for decades post-injury (Holsinger et al., 2002).

Brain injury can also increase the risk for developing other psychiatric disorders such as mania and psychotic disorders (McAllister, 1992), as well as risk of suicide attempts (Silver et al., 2001). The development of post-traumatic stress disorder (PTSD) symptoms has also been found, even among individuals with PTA and no memory for the event. Prevalence rates for PTSD are estimated to be between 3% and 27% (Kim et al., 2007). Additionally, lack of awareness regarding the emotional changes and limitations following injury have often been seen among individuals with severe TBI (O'Keeffe et al., 2007). Other research has suggested that those with mild TBI are aware of their

emotional changes and limitations post-injury (Coolidge, Mull, Becker, Stewart, & Segal, 1998). In contrast, Chan and Manly (2002) found a sample of individuals with mild to moderate TBI rated themselves as having greater executive abilities such as abstract thinking, control of impulsivity, and planning than the level observed by relatives who also rated them in these areas. It appears that for some individuals with TBI, awareness of deficits is lacking, but this is not always the case.

Several potential long-term deficits have also been found among individuals with moderate and severe TBI. Colantonio and colleagues (2004) completed one of the largest long-term outcome studies in the U.S. by following-up 306 survivors of moderate to severe TBI 24 years after discharge from inpatient programming. Results of the review showed significant impairments on cognitive testing related to memory and psychomotor speed. In terms of daily living, participants identified their greatest limitation as managing money. Mobility and community integration were also found to be poor. Other long-term outcome studies have found difficulties with social functioning among survivors of severe TBI, as well as high levels of stress reported by family members who care for these individuals (Brooks, Campsie, Symington, Beattie, & McKinlay, 1986; Hoofien, Gilboa, Vakil, & Donovan, 2001).

In addition to the potential cognitive, physical, and emotional problems just described, a TBI also increases a person's risk for future brain injury. Research has shown that individuals who experience multiple instances of TBI, often called recurrent TBI, are at an increased risk for future brain injury and a cumulative decline in functioning (Salcido & Costich, 1992). Recurrent TBI is often described in the sports literature, where it is also referred to as second impact syndrome (SIS), as a risk factor for

future brain injury and significantly greater neurological impairment (Webbe, 2006). Research regarding the effects of repeated injuries is limited and inconsistent, particularly in the case of multiple mild TBIs. While some research suggests that there is no significant or cumulative effect after multiple injuries (McCrea, 2008), other studies have found poorer performance on memory and executive functioning tests (Belanger et al., 2010) and poorer functional outcomes (e.g., returning to work) when comparing individuals with a history of multiple injuries to others with only one (Stulemeijer et al., 2006). The long-term consequences of multiple sport-related TBIs have recently been identified as a potential area of concern and one where more research is needed (Randolph & Kirkwood, 2009).

Taken together, the general TBI research literature indicates a variety of serious and potentially long-term consequences that result from TBI. The deficits are varied and often interrelated, which leaves individuals who survive a TBI having to cope with multiple deficits that affect many areas of their life. Further, there is potential for deficits following a TBI of any severity level, as well as a number of different symptom presentations following similar types of injuries. Similar to the general TBI literature, the corrections specific TBI literature has also demonstrated significant deficits related to these injuries, which will be reviewed next.

Implications of TBI in Offender Populations

There is a small but growing body of research looking at the implications of TBI in correctional and justice-involved populations. Some of this research is similar to the general TBI research in that it has attempted to describe the cognitive, emotional, and behavioral sequelae of TBI. However, a significant portion of TBI research using

incarcerated samples has focused specifically on TBI as it relates to violent criminal behavior. Researchers have explored possible links between TBI and domestic violence (Rosenbaum et al., 1994; Turkstra, Jones, & Toler, 2003; Marsh & Martinovich, 2006), murder (Lewis et al., 1986), and mixed violent offenses (Leon-Carrion & Ramos, 2003; Brewer-Smyth, Burgess, & Shults, 2004).

Other research has investigated general criminal activity, cognitive functioning, emotional adjustment, (Sarapata et al., 1998), executive functioning (Cohen et al., 1999), institutional adjustment (Merbitz et al., 1995; Shiroma et al., 2010), and the neuropsychiatric correlates of impairment (Schofield et al., 2006; Slaughter et al., 2003) as they relate to TBI. It is important to note that there are some key differences between the type of research looking at TBI in correctional and offender populations and the general TBI research that may contribute to the focus on TBI in relation to violence. Whereas much of the general research describing TBI deficits and outcomes is conducted with individuals involved in inpatient or outpatient medical care for a known incident of TBI, the vast majority of research describing TBI in correctional populations consists of individual's self-report of TBI events that have occurred in their lifetime. The general research tends to focus on the level of severity of the injuries experienced and the consequences and functional limitations that are seen during the rehabilitation period following the injuries. In contrast, the TBI research involving correctional populations has often looked for causal or correlational relationships between criminal behavior and TBI.

In terms of both general and violent criminal behavior, as well as antisociality, much work has explored the role neuropsychological deficits and brain damage in general

(i.e., not necessarily from TBI) may play as potential contributing factors to criminal behavior (Langevin, Ben-Aron, Wortman, Dickey, & Handy, 1987; Nestor, 1992; Golden, Jackson, Peterson-Rohn, & Gontkovsky, 1996; Miller, 1999b). The term 'brain damage' often connotes evidence of structural damage to the brain that has been identified with imaging techniques such as CT or MRI. In other cases researchers infer that an individual has brain damage based on their performance on neuropsychological tests. For example, in a review of the literature examining violence and aggression, Golden and colleagues (1996) found that violent adult offenders tended to have higher levels of neuropsychological indicators of brain damage. However, they also pointed out that not all offenders with brain damage become violent, and factors such as premorbid aggression, substance use, and stress level post-damage can play a role. One study in particular found that almost three-quarters of an offender sample with known brain damage had committed violent offenses, compared to one-third of a group without brain damage (Bryant et al., 1984). In terms of antisocial behavior, Morgan and Lilienfeld (2000) completed a meta-analysis and found a significant relationship between deficits in executive functioning and general antisocial behavior. Similarly, a longitudinal study following individuals from adolescence into adulthood found that frequent physical violence was associated with lower cognitive performance, including executive functioning (Barker et al., 2007). Other research has found deficits in one area of executive functioning, behavioral inhibition, were significantly predictive of treatment outcomes in a sample of 224 male inmates (Fishbein et al., 2009). Additionally greater deficits in executive functioning have been found when comparing offenders to non-offenders (Baker & Ireland, 2007).

The role TBI plays in criminal behavior has also been explored, though to a lesser degree than research that looks at general neuropsychological deficits and crime. The TBI research has typically looked for a potential causal relationship with offending behaviors. In a review of the literature, Miller (2002) found evidence suggesting a possible link between frontal brain injuries and violent offenses. Others have also made the connection between frontal damage and crime due to the impact frontal damage has on executive functioning, such as perception of social situations and impulse control (Diaz, 1995). One study examining whether head injury predisposed individuals to violent behavior compared a group of 36 violent offenders to 13 offenders convicted of non-violent “white-collar” crimes. All offenders were interviewed regarding their educational, behavioral, and medical history to determine if there was a history of problems in school as well as any history of head injury. The only significant difference found between the groups was a higher rate of reported childhood head injury in the violent offender group (Leon-Carrion & Ramos, 2003). Rosenbaum and colleagues (1994) compared histories of TBI (mild, moderate, and severe) in groups of male batterers, maritally discordant men, and maritally satisfied men, and found rates of 53%, 25%, and 16% respectively. Further, they found that “the occurrence of head injury preceded both aggression toward the wife and other assaults and batteries in almost every case” (Rosenbaum et al., 1994, p. 1192). A higher rate of deficits in executive functioning has also been found for male batterers when compared to men with no history of committing domestic violence (Cohen et al., 1999).

Marsh and Martinovich (2006) looked at a sample of 38 men involved in domestic violence programming who also had a history of at least one violent offense.

More than half the sample had experienced at least one TBI, and among those with a history of TBI half of the injuries were classified as severe. Further, those with a history of TBI performed worse on measures of executive functioning than those without a history of TBI. Lewis and colleagues (1986) explored the neuropsychiatric status of 15 inmates sentenced to death for committing murder and found that all had a history of multiple head injuries. A more recent study that also looked at neuropsychological functioning in a sample of individuals charged or convicted of murder found that 87% reported a history of head trauma, and the majority of those demonstrated executive dysfunction (Hanlon et al., 2010). Hancock, Tapscott and Hoaken (2010) found that scores on executive functioning tests related to the frequency and severity of violent offending in a sample of 77 adult male offenders. Brewer-Smyth and colleagues (2004) compared 27 violent and 86 non-violent female offenders and found that while both groups had significantly higher rates of TBI than the general population (56% of violent offenders, 38% of non-violent offenders), the TBI rate for violent offenders was significantly higher than that of the non-violent group.

Research has also suggested that brain injury may be related more generally to increased rates of arrest, conviction, and incarceration following the injury (Miller, 1999a; Miller, 2002). Sarapata and colleagues (1998) completed three small-scale studies looking at a community corrections sample. Among 23 non-violent offenders they found that 83% of those with a history of TBI reported the injury had occurred prior to their offense. Additionally, offenders with a history of head injury reported significantly poorer cognitive functioning and emotional adjustment than offenders without head

injury and a control group. They also found generally poorer functioning and adjustment in the head injured offenders, though the difference was not statistically significant.

Schofield and colleagues (2006) also looked at emotional and psychological factors in a sample of 200 prison entrants and found head injuries were positively correlated with positive screens for depression and psychosis. Furthermore, 43% of those with a history of TBI reported sustaining four or more in their lifetime. A large-scale birth cohort study conducted in Northern Finland found that TBI during childhood or adolescence significantly increased risk for co-occurring criminal activity and mental illness in adulthood (Timonen et al., 2002).

Finally, research has also suggested that TBI has an impact on how incarcerated individuals adjust to the institution and their preparedness for re-entry into the community. In terms of institutional adjustment, research has shown that offenders with head injury receive significantly more disciplinary infractions while incarcerated (Merbitz et al., 1995; Shiroma et al., 2010). Offenders with mental disorders and a history of head injury have also been assessed to be a significantly greater risk to themselves and others upon release (Hawley & Maden, 2003).

As described above, there are several factors that can play a role in how an individual is impacted by a TBI including the severity of injury and premorbid factors such as substance abuse, neuropsychiatric history, and age at injury. These factors are particularly salient for research involving incarcerated populations as rates of substance abuse, psychiatric history, and other pre-morbid factors are higher than those found in the general population (James & Glaze, 2006; Hanlon et al., 2010). As a result of these potentially confounding factors and the controversial nature of exploring potential

biological contributions to antisocial and violent behavior, almost all researchers working on these issues strongly emphasize that TBI is only one of several factors contributing to violence and antisocial behavior.

In contrast to attempts to isolate the impact of TBI, a more comprehensive view of an individual's deficits that incorporates multiple contributing factors may be more accurate and useful when examining the influence of brain injury on incarcerated populations, especially when considering the high rates of co-occurrence of TBI and other related variables. For example, Cohen and colleagues (1999) conducted research looking at the relationship between neuropsychological functioning and domestic violence. They found that impairments in neuropsychological functioning were significantly correlated with domestic violence, but a stronger relationship was found when the additional factors of prior head injury and current emotional distress were also taken into account. The current study attempted to take a more comprehensive approach by using cognitive reserve theory to explore the impact of multiple variables on executive functioning.

Summary and Conclusions

Traumatic brain injury (TBI) is a significant public health concern in the United States population as a whole as well as within the nation's incarcerated population. Regardless of the severity level of the injury, individuals can experience emotional, behavioral, cognitive, and social deficits following a TBI. Further, these deficits can be of short- and long-term duration and have an impact on the individual, their family, and society. In terms of incarcerated individuals, the research seems to indicate that the problem of TBI is even greater than for the general population as the incidence of TBI

seems to be much higher among the incarcerated. The recognition of TBI as a public health issue has encouraged research in this area to determine the prevalence of TBI and the implications it has for individuals.

One of the primary barriers to determining prevalence rates of TBI in any population is the lack of a consistent approach to defining TBI. Over time, several definitions have been developed and factors such as loss of consciousness (LOC) and posttraumatic amnesia (PTA) are being used more consistently for defining TBI in research. The CDC and other major health-related organizations have developed definitions of TBI and urged researchers to use them in order to increase consistency across studies, thereby allowing results to be generalized (National Center for Injury Prevention and Control, 2003; ACRM, 1993). As a result of these efforts, TBI is now commonly classified into three injury severity levels including mild, moderate, and severe. A significant amount of research has looked at the various severity levels, particularly mild and severe, in terms of the short- and long-term outcomes that follow. Much of this research has examined samples drawn from groups receiving inpatient or outpatient medical care for a known incident of TBI, and has looked at cognitive, psychological, and social outcomes for the purposes of rehabilitation. In contrast, much of the research using samples of incarcerated individuals has been based on self-reported histories of head injury, often from their remote past, and the research has focused on relationships between TBI and criminal activity or violent behavior.

Almost all studies examining TBI in correctional samples have reported rates of TBI that are much higher than rates found in the general population, suggesting that overall rates of TBI among the nation's incarcerated are high. There are a number of

methodological problems with the existing research, however, that make it difficult to generalize from these results to the entire incarcerated population. First and foremost, the methods for identifying and classifying TBI have been highly inconsistent across studies. Some studies used LOC as their method for classifying TBI (Rosenbaum et al., 1994; Morrell et al., 1998; Marsh & Martinovich, 2006), while others were not able to gather LOC data for the majority of their sample (Hawley & Maden, 2003; Colantonio et al., 2007). Some researchers created their own classification system to describe injury severity (Hawley & Maden, 2003; Turkstra et al., 2003) while others did not report severity levels (Sarapata et al., 1998; Brewer-Smyth et al., 2004). Very few studies were found to have used the CDC, ACRM, or WHO definitions of TBI described above (e.g., Diamond et al., 2007; Schofield et al., 2006; Slaughter et al., 2003).

All of the studies reviewed in the above literature review that examined TBI in correctional populations gathered retrospective self-report data on incidents of head injury and TBI over the lifetime. One research study that looked at the reliability of self-reported TBI in an incarcerated sample found the majority of participants gave a generally accurate report as compared to their medical record, providing some support for the use of self-report (Schofield, Butler, Hollis & D'Este, 2011). While this is the only practical option available in many cases, methodologies varied dramatically in terms of efforts to verify instances of head injury that actually resulted in TBI. Some studies gathered corroborating data from medical records when available or involved a physician in the interview process to assess for TBI symptoms (e.g., Rosenbaum et al., 1994; Brewer-Smyth et al., 2004). Hawley and Maden (2003) used a chart review as their sole source of information on past TBI and the absence of any reported TBI in the chart was

considered the absence of a history of TBI. Very few studies looked for neuropsychological evidence of TBI-related deficits (e.g., Slaughter et al., 2003; Barnfield & Leathem, 1998b).

Generalizing from the available research is also complicated as a result of the highly varied samples that were examined across studies. Research has been conducted with samples of federal prisoners (Diamond et al., 2007), state prisoners (Morrell et al., 1998), county jail inmates (Slaughter et al., 2003), offenders in the community (Sarapata et al., 1998), forensic psychiatric patients (Hawley & Maden, 2003), and inmates on death row (Lewis et al., 1986). The heterogeneity of these samples makes drawing overall conclusions from the research difficult, despite the seemingly consistent finding that rates of TBI are high across all studies. In fact, a subgroup of the CDC's TBI workgroup reported they had "determined that information about special populations [including correctional settings] is not of sufficient quantity or quality to recommend MTBI [mild TBI] surveillance methods" (National Center for Injury Prevention and Control, 2003, p.5). They recommended that stakeholders conduct more research and standardize the way data are collected in order to address this problem.

The existing research has primarily looked at the relationship between TBI and violence, and has shown that rates of violence are higher among individuals with TBI (Rosenbaum et al., 1994; Leon-carrion & Ramos, 2003; Brewer-Smyth et al., 2004). Research has also demonstrated higher rates of violence among individuals with executive functioning deficits (Cohen et al., 1999; Hancock et al., 2010). General antisocial behavior (Morgan & Lilienfeld, 2000) and poorer treatment outcomes (Fishbein et al., 2009) are also associated with executive functioning deficits. Given the

existing evidence from community-based research that TBI can lead to significant deficits in cognitive abilities, and especially executive functioning (i.e., volition, planning, inhibition, and effective performance), it is surprising that little research has looked at TBI and executive functioning in offender samples. The few existing studies demonstrated higher rates of executive functioning deficits among individuals with a history of TBI (Marsh & Martinovich, 2006; Hanlon et al., 2010). More research that examines this relationship and its influence on behavioral outcomes is needed.

Given that co-occurring confounding variables are often present in incarcerated samples (e.g. substance abuse, psychiatric history, multiple injuries), research that provides a more comprehensive view of an individual's deficits and that incorporates multiple contributing factors is badly needed. Cognitive reserve theory would provide a good foundation for research that incorporates multiple contributing factors. The theory states that cognitive reserve is involved in how the brain is impacted by an injury and how it recovers from it. Higher reserve levels can act as a protective factor from the development of the remote sequelae of brain injury, and lower levels would be a risk factor (Stern, 2002). Research has supported the use of cognitive reserve theory in explaining the heterogeneity of outcomes following TBI in community samples. Given the high incidence of multiple neurological risk factors found in incarcerated samples, it appears to be a promising theory for further TBI research with this population.

Taken together, the research clearly indicates that TBI is a significant public health concern, and especially within correctional populations. A considerable amount of research looking at the implications of TBI has been done in community and hospital settings, though research in correctional settings has been much more focused on violent

and criminal behavior. As a result, other cognitive, emotional, behavioral and social consequences of TBI have yet to be examined. The current study will help to address this gap in the research by looking at executive functioning and its relationship to TBI and subsequent behavior in a sample of adults incarcerated in the federal prison system.

CHAPTER THREE METHODS

This study was conducted using archived data collected as part of two larger studies looking at mental health and traumatic brain injury in federally incarcerated adults. In the following sections, the participants, instruments, and procedure used in the present study are described.

Study Participants

The current study used archival data gathered from a sample of adult men and women incarcerated by the Federal Bureau of Prisons (BOP) who participated in a study that established the reliability and validity of the Traumatic Brain Injury Questionnaire (TBIQ) (Diamond et al., 2007). These individuals were a subset of a larger sample who had participated in an earlier study of mental health needs within the BOP called the Mental Health Prevalence Project (MHPP) (Magaletta, Diamond, Faust, Daggett, & Camp, 2009). The MHPP used a purposeful sampling method in order to maximize the representativeness of the sample and to control for the costs of gathering data at multiple sites across the United States (Magaletta et al., 2009). The researchers used a nonprobability continual sampling strategy, and stratified for gender and security level. They over-sampled for women and for men from high-security facilities to ensure adequate representation of these groups. The sample for the MHPP consisted of 2,221 men and 634 women drawn from 14 federal prison sites across 3 security levels. Self-report data, screening, and intake data were collected. Eligibility criteria included the following: 18 years of age or older, 4th grade or higher literacy level, new admission to

the federal prison system on a new charge, and the physical and mental ability to respond to self-report measures in English or Spanish (Magaletta et al., 2009).

Six of the 14 prisons that participated in the MHPP were selected for inclusion in the TBIQ study. These sites were chosen to ensure women were well represented and to minimize travel costs related to gathering the interview data. Four sites housed male inmates (two minimum, one medium, and one maximum) and two sites housed minimum-security female inmates. All 308 inmates housed in the 6 facilities who had participated in the MHPP were approached for recruitment into the TBIQ study, and 225 (118 women and 107 men) subsequently completed interviews. Interviews were conducted that included the Neurobehavioral Rating Scale-Revised (NRS-R) and the TBIQ, followed by administration of a brief battery of neuropsychological tests and self-report measures (Diamond et al., 2007).

Several steps were taken to ensure the data collected were true and accurate. No incentive was offered to participants and all data collected remained confidential. Interviews were conducted by individuals from outside the institution, and none of the results were shared with the institutions. Additionally, a portion of the sample was given the TBIQ a second time and test-retest reliability was quite good ($r = .90$), suggesting the self-report data provided by participants was consistent across administrations.

The current sample included 224 adults (106 men, 118 women). One case was deleted from the sample after it was determined that scores for the majority of the neuropsychological tests were missing. Participants ages ranged from 21 to 64 ($M = 36.67$, $SD = 9.3$). The majority of the sample was Caucasian ($n = 124$, 55.4%), followed by African American ($n = 96$, 42.9%), Asian ($n = 3$, 1.3%), and American Indian ($n = 1$,

0.4%). Level of education ranged from 1 to 17 years completed ($M = 10.73$, $SD = 2.7$, median = 11, mode = 12). In terms of criminal records, 56.4% of the sample had at least one prior offense and 26.8% had a history of violence. The majority of the sample was currently incarcerated for a drug offense (64.9%), and 27.1% were in for a violent offense. See Tables 3.1 – 3.5 below for additional demographic information.

Table 3.1

Range and Means (Standard Deviations) of Demographic Variables			
	Range		Mean (SD)
	Minimum	Maximum	
Age (N=224)	21	64	36.67 (9.30)
Years of Education (N=224)	1	17	10.73 (2.69)
IQ (N=224)	61	131	92.26 (12.23)

Table 3.2

TBI Severity Levels Reported in the Sample (median severity = moderate/severe, mode severity = moderate/severe)		
TBI Severity Level	Frequency	%
no head injury	28	12.5
at least 1 mild TBI	71	31.7
at least one moderate/severe TBI	125	55.8

Table 3.3

Severe Mental Illness and Substance Abuse Diagnoses Within the Sample		
	Frequency	%
Substance Abuse Diagnosis (N=222)	149	66.5
Severe Mental Illness (N=207)	47	21

Table 3.4

Measures of Central Tendency for Institutional Behavior Variables			
	Mean	Median	Mode
# of Psychological Services Visits (N=224)	7.01	3.5	2
# of Behavioral Infractions (N=224)	1.08	0	0

Table 3.5

Current and Past Criminal Behavior Within the Sample	
Prior Criminal History	
Age at first arrest: median (range)	20 (8-54)
Prior Incarceration (% yes)	56.4
History of Violence (% yes)	26.8
Current Incarceration	
Violent Offense (% yes)	27.1
Drug Offense (% yes)	64.9

note: Age at first arrest, prior incarceration, violent offense, and drug offense data drawn from (Diamond et al., 2007)

Sample Size and Power Analysis

Statistical power is the probability of correctly rejecting the null hypothesis when it is false, and it is a function of several factors including effect size, significance level (α), and sample size (Hair, Black, Babin, Anderson, & Tatham, 2006; Kline, 2011). Unlike simple procedures such as the t-test or ANOVA, structural equation modeling (SEM) involves considerably more parameters which can make a power analysis to determine adequate sample size difficult. However, a number of guidelines have been suggested to aid researchers in determining sample size. One method that has some empirical support is the $N:q$ rule which suggests that minimum sample size be determined by the number of estimated parameters (Jackson, 2003). However,

recommended values for the ratio that is calculated vary. Kline (2011) recommends that the ratio fall between 10:1 and 20:1, while Klem (2000) suggests the ratio should fall between 5:1 and 10:1. Other suggested guidelines include 10 to 20 participants per observed variable (Thompson, 2000), and a minimum sample size of 100 to 200 for a full analysis (Klem, 2000; Thompson, 2000). The proposed model of the current study contains 24 estimable parameters, 7 observed variables, and a sample size of 224. This means the N:*q* ratio was 9.3:1 and there were 32 participants per observed variable.

Measures

The current study used demographic data, neuropsychological test data, and self-report data from several measures collected during the course of the MHPP and TBIQ studies described above. Demographic data were derived from the Psychology Services Inmate Questionnaire (PSIQ), the SENTRY data system, the Psychology Intake Interview from the Psychology Data System (PDS), and the Pre-Sentencing Investigation and Coding form (PSI-CF). Traumatic brain injury data came from the Traumatic Brain Injury Questionnaire (TBIQ). The neuropsychological tests included were the General Ability Measure for Adults (GAMA), the Hopkins Verbal Learning Test – Revised (HVLT-R), the Wisconsin Card Sorting Test-64 card version (WCST-64), the Symbol Digit Modalities Test (SDMT), the Trail Making Test (TMT), and the Grooved Pegboard test.

The Psychology Services Inmate Questionnaire (PSIQ)

The PSIQ is a self-report form filled out by all inmates entering the BOP as part of the psychology services intake screening process. It is two pages long and consists mainly of yes/no questions regarding past criminal history, mental health history, and

demographic information. The PSIQ also includes two checklists, one regarding drug use for the two years preceding arrest and one regarding the experience of any recent psychological symptoms. The PSIQ is completed prior to a clinical interview with a BOP doctoral-level psychologist which allows the psychologist to review the inmate's self-reported prior history, along with other criminal and mental health records, in advance of the clinical interview (Diamond, Magaletta, Harzke, & Baxter, 2008).

SENTRY

The BOP uses a centralized electronic database for offender tracking and data management. The SENTRY system includes demographic data, sentencing information, institution classification information, institutional adjustment data, and other information for all offenders in BOP custody (Magaletta et al., 2009; Diamond et al., 2007). Data retrieved from SENTRY for the MHPP and TBIQ studies included demographics and relevant criminal history (MHPP), as well as information regarding any past history of violence, and disciplinary infractions incurred during the first 24 months of the current incarceration (TBIQ study) (Magaletta et al., 2009; Diamond et al., 2007).

Psychology Intake Interview from the Psychology Data System (PDS)

The PDS is a component of the electronic mental health record that is maintained for all BOP offenders (Magaletta et al., 2009). The results of the clinical interview conducted with inmates as part of the psychology services intake screening process are entered into the PDS. The format of the intake within the PDS consists of a set of specific response categories that are meant to be a general guide for the intake interview process (Magaletta et al., 2009). Data retrieved from the PDS for the MHPP and TBIQ study included reported lifetime history of inpatient psychiatric hospitalization, any current

diagnosis of serious mental illness, and reported or known history of psychotropic medication use (MHPP). Additional data included reported substance abuse history and number of mental health contacts during the first 24 months of the current incarceration (TBIQ study) (Magaletta et al., 2009; Diamond et al., 2007).

Pre-Sentence Investigation and Coding Form (PSI-CF)

A Pre-Sentence Investigation (PSI) is a report that is generated to provide background and historical information about a defendant to the court to help with dispositioning the case. The PSI is ordered by the judge and is completed by a trained probation officer. The probation officer conducts an investigation which typically includes an interview with the defendant regarding family, personal, medical, mental health, substance use, education/employment, and criminal history. Information is corroborated by interviews with relevant family members when possible, as well as through a review of past public health and safety records. The final result of the investigation is a narrative description of the defendant's current offense and the background information gathered by the agent (Magaletta et al., 2009).

Some of the data collected for the MHPP was drawn from the PSIs of the study participants, and in an effort to make data collection more uniform the researchers created the PSI-CF. The researchers first identified what variables could be reliably coded from a PSI and then created a coding protocol and training manual that explicated the coding procedures they had developed. Data coded with the PSI-CF included family and childhood history, educational history, history of suicide attempts or self-harm, history of head injury, and detailed mental health and substance abuse information. Some information was also coded as "self-report" or "verified" if the information had come

from a source other than the offender. Six individuals were trained as coders through an intensive two-day training program, and each coder was required to reach 90% agreement with 10 criterion protocols prior to independently coding protocols (Magaletta et al., 2009).

Traumatic Brain Injury Questionnaire (TBIQ)

The TBIQ screening instrument was developed specifically for use with offender populations. It utilizes a structured interview format to gather information on total number, frequency, and severity of instances of head injury by inquiring about several types of incidents that could lead to TBI (e.g., vehicle accidents, falls, sports injuries, assaults). After determining the number of each type of head injury, the interviewer gathers information regarding the circumstances surrounding the injury and determines injury severity based on loss of consciousness (LOC), posttraumatic amnesia (PTA), and need for medical treatment. The measure also includes a symptom checklist inquiring how often the respondent has experienced 15 different cognitive and behavioral symptoms (e.g., “easily distracted,” “trouble doing more than one thing at a time”). The interviewer codes the time frame for the symptoms as “current,” “within the past year,” “more than one year ago,” or “never had.” The measure yields symptom scale scores for symptom severity and symptom frequency (Diamond et al., 2007).

An initial study was conducted to establish the reliability and validity of the TBIQ with a sample of 225 federal prisoners selected from three security levels (low, medium, and high security). Participants were interviewed with the TBIQ and administered several other empirically validated measures of common symptoms associated with TBI including the Neurobehavioral Rating Scale-Revised (NRS-R) for cognitive and

behavioral symptoms (McCauley et al., 2001) and the Center for Epidemiologic Studies Depression Scale (CES-D) for depression symptoms (Radloff, 1977). A portion of the sample was re-administered the TBIQ two to four weeks later to determine test-retest reliability. Results indicated test-retest reliability was adequate ($kappa = .56$) regarding lifetime prevalence of head injuries, and excellent ($r = .90$) regarding frequency of head injury. Internal consistency was high (symptom frequency $\alpha = .92$; symptom severity $\alpha = .87$) for both symptom scales. Criterion validity of the TBIQ was supported through the statistically significant differences found between the “no TBI” group as compared to those with a history of TBI on symptom frequency and severity scale mean scores, along with the majority of the psychological and behavioral scales administered. Finally, the TBIQ was found to detect TBI related symptoms more reliably than the standard inmate intake questionnaire (Diamond et al., 2007).

The General Ability Measure for Adults (GAMA)

The GAMA is a nonverbal test designed to be a general measure of cognitive ability. The authors state that it “evaluates an individual’s overall general ability with items that require the application of reasoning and logic to solve problems that exclusively use abstract designs and shapes” (Naglieri & Bardos, 1997, p.1). The GAMA consists of 66 test items within four subtests: matching, analogies, sequences, and construction. The subtest scores do not represent different kinds of abilities but are meant to capture different measurements of the person’s overall general ability (Bardos, 2003). The GAMA is a self-administered test that can be administered to an individual or a group, and the standardization sample consisted of 2,360 people between the ages of 18 and 96 to allow for age specific norms. The sample was found to closely approximate the

overall US population in 1990 based on demographics such as age, gender, and race/ethnicity. Seventy-five percent of the normative sample was Caucasian (Naglieri & Bardos, 1997). The measure produces an overall IQ score with a mean of 100 and a standard deviation (*SD*) of 15. Subtest scores can also be calculated to determine strengths and weaknesses.

The GAMA has been found to be reliable, and the median internal consistency for the GAMA total score showed a reliability coefficient of .90 across all age groups (Bardos, 2003). Further, a review of the research literature indicated that the GAMA is a valid instrument for measuring overall cognitive ability and has been correlated with Wechsler Adult Intelligence Scales (WAIS; both the WAIS-R and WAIS-III; Wechsler, 1981; Wechsler, 1997) when used with several different normal and clinical populations (Bardos, 2003). Among a sample of 60 adults with TBIs ranging from mild to severe, the GAMA IQ score was found to strongly correlate with the WAIS-III full scale IQ ($r = .80$, $p < .0001$) (Martin, Donders, & Thompson, 2000). More recently, the GAMA was found to successfully differentiate a group of individuals with neurologic impairment (with 80% of the sample having a head injury) from a control sample, and the GAMA IQ score was found to significantly correlate with the Kaufman Brief Intelligence Test ($r = .59$, $p < .001$; K-BIT; Kaufman & Kaufman, 1990) (Davis, Bardos, & Woodward, 2006).

Hopkins Verbal Learning Test – Revised (HVLT-R)

The HVLT-R is a brief assessment of verbal learning and memory and consists of 12-item word lists with six alternate forms (Brandt & Benedict, 2001). It is modeled after other word-list learning tasks, although the HVLT-R has a shorter word list (12 words) than others (16 words). The HVLT-R consists of three learning trials during which the

list is read to the examinee, and they are asked to recall as many words from the list as possible. After a time delay, the examinee is asked to recall the list again (free recall trial), and is then administered a yes/no delayed recognition trial consisting of a list of 24 words including the original 12 and 12 foil words (Strauss, Sherman, & Spreen, 2006). The test provides four scores including total recall, delayed recall, percent retention, and a recognition discrimination index which are converted to T scores with age-based tables (Brandt & Benedict, 2001). In terms of demographics, age has been found to have the largest effect on HVLТ-R performance. Research regarding the impact of education and IQ has been inconsistent and the impact of race/ethnicity was not reported in the standardization sample (Strauss et al., 2006). The standardization sample included 1179 individuals with no known history of neurologic disorder and ages ranging from 16 to 92 years.

Test-retest reliability was found to be adequate for the total recall score in a sample of 40 adults ($r = .74$, $p < .001$), though delayed recall ($r = .66$), percent retained ($r = .39$), and recognition discrimination ($r = .40$) were in the marginal to low range (Benedict, Schretlen, Groninger, & Brandt, 1998). It has been suggested that the low temporal stability of this measure relates to the low number of trials, although Strauss and colleagues note that “the same pattern emerges when the 16-item version of the CVLT-II [California Verbal Learning Test – 2nd Edition] is used” (2006, p.762). The HVLТ-R consists of three trials, while the CVLT-II has five trials (Delis, Kramer, Kaplan, & Ober, 2000). The HVLТ-R has shown convergent validity with the CVLT for total recall ($r = .74$) (Lacritz & Cullum, 1998) and has been found to correlate with other tests of verbal

memory including the Wechsler Memory Scales – Revised Logical Memory subtest ($r = .65$ to $.77$) (Shapiro, Benedict, Schretlen, & Brandt, 1999).

Research exploring the use of the HVLTR with TBI populations has been limited although it has been recommended for use in TBI screening as an alternative to lengthier procedures, and because the alternate forms allow for multiple assessments over time (Lynch, 2002). In a study examining predictors of post-concussive syndrome among individuals with minor head injuries, the HVLTR was found to be useful in predicting those who would later have post-concussive symptoms (Bazarian et al., 1999).

The Wisconsin Card Sorting Test – 64 Card Version (WCST - 64)

The Wisconsin Card Sorting Test (WCST) was designed to assess a person's ability to form abstract concepts, to shift and maintain set, and to utilize feedback (Strauss et al., 2006). It has been identified as the most frequently used test for assessing executive functioning in a survey of neuropsychologists across North America (Rabin, Barr, & Burton, 2005). The WCST is a problem-solving task that consists of four stimulus cards, each with a different colored shape printed on them (1 red triangle, 2 green stars, 3 yellow crosses, and 4 blue circles). These 4 cards are placed in front of the subject, and they are then given 2 packs of response cards with 64 cards in each pack. These cards have similar designs to the stimulus cards, though they vary in color, geometric shape, and number of shapes on each card. The subject is asked to match each card from the deck to the key card they think it matches, and they receive feedback from the examiner as to whether or not their match is correct. The examiner does not give any other information regarding how the cards are to be matched. The examiner's feedback is based on a sorting rule (e.g., match for color) which changes after the subject achieves 10

correct matches. The subject is not told the sorting rule and must use the examiner's feedback to determine the sorting principle. The test is complete after the subject achieves six categories, or after all the cards have been placed (Heaton, Chelune, Talley, Kay, & Curtis, 1993). The WCST-64 is a short form of the WCST in which only one deck of cards is used (Kongs, Thompson, Iverson, & Heaton, 2000).

There are a number of ways the individual's performance can be scored including the following: number of categories completed, trials to complete first category, perseverative responses, perseverative errors, and failure to maintain set. The number of categories achieved and the number of perseverative errors are the most common scores used to assess executive functioning. A complete category consists of 10 consecutive correct matches, and a failure to maintain set occurs when the person matches at least five cards correctly but makes an error before successfully completing the category. Perseverative responses occur when the subject persists in responding to a stimulus characteristic that is incorrect (e.g., a color category has been completed and the sorting rule is now for geometric form, but the subject continues matching based on color). Scoring of the WCST is quite complicated and a computer-scoring program has been created to reduce scoring errors (Strauss et al., 2006).

Research has shown that age has the strongest relationship to WCST performance, and education level has been found to have a modest effect (Strauss et al., 2006). The research regarding the influence of gender has been mixed. Data regarding race and ethnicity of the standardization sample were not reported, though subsequent research has provided normative data for Spanish-speaking individuals (Artiola I Fortuny, Heaton, & Hermsillo, 1998) and Italians (Laiacina, Inzaghi, De Tanti, & Capitani, 2000). The

standardization sample consisted of 899 neurologically normal subjects ranging in age from 6 years, 5 months to 89 years, and scoring tables are provided based on the person's age or a combination of age and level of education achieved (Heaton et al., 1993). The WCST-64 has a separate scoring manual (Kongs et al., 2000) that was created using the same data used for the WCST manual (Heaton et al., 1993). Additionally, Iverson, Slick, and Franzen (2000) developed a set of norms for use of the WCST-64 with individuals who experienced mild uncomplicated head injury.

A number of research studies have looked at the test- retest reliability of the WCST in many different clinical and normal populations and have often shown a significant practice effect (Strauss et al., 2006). One rationale for this practice effect is that after a person with reasonably intact memory has figured out the sorting and shifting principle, they retain their problem-solving strategy, and the WCST is no longer measuring problem solving-abilities (Lezak et al., 2004). However, reliability does appear to be somewhat higher in clinical samples for some of the WCST scores, including perseverative errors (Strauss et al., 2006). One study looking at the reliability of the WCST-64 found it to be poorer than that of the WCST, though a major caution for interpreting these results was made due to the fact that the WCST-64 scores were extracted from samples who had taken the full WCST two times. Thus, participants had as much as twice the exposure to the task than would normally occur for the WCST-64 (Greve et al., 2002).

Factor analysis has been used in a variety of WCST studies, and most support a three-factor solution consisting of ability to shift set, problem solving/hypothesis testing, and response maintenance, with the first factor of ability to shift set being the most

statistically sound (Strauss et al., 2006). Research comparing the WCST to other neuropsychological measures has produced varied results. Some have found modest correlations with measures of attention and working memory (Pukrop et al., 2003), while others have found no correlation (Paolo, Troster, Axelrod, & Koller, 1995). When comparing the WCST to other tests of executive functioning, the WCST has tended to load on a separate factor due to the various tasks measuring different aspects of executive functioning (Strauss et al., 2006). Regarding the two forms, a number of studies have found the WCST and the WCST-64 scores to be highly correlated with r values above .7 (Axelrod, 2002; Sherer, Nick, Millis, & Novack, 2003). Finally, the WCST has been found to be particularly sensitive to frontal brain damage (Heaton et al., 1993; Strauss et al., 2006) and, for the most part, research has supported the use of both the WCST and the WCST-64 for individuals with traumatic brain injury (Love, Greve, Sherwin, & Mathias, 2003; Sherer et al., 2003; Ord, Greve, Bianchini, & Aguerrevere, 2010).

Trail Making Test (TMT)

Neuropsychologists commonly use the TMT to assess attention and executive functioning (Rabin et al., 2005). It is a test of attention, speed, visuomotor tracking, and mental flexibility (Lezak et al., 2004). The test consists of two trail making tasks, Part A and Part B, and each trial begins with a practice. Part A consists of 25 encircled numbers that are printed randomly across the page, and the examinee is to connect the numbers in order as quickly as possible. Part B contains 25 encircled numbers and letters, and the examinee is to connect them in order alternating between numbers and letters (e.g., 1 to A, A to 2, 2 to B) as quickly as possible. The examiner provides feedback if the examinee makes an error, and the test is discontinued if it has not been completed within five

minutes (Strauss et al., 2006). The TMT yields two scores that consist of the total time it takes to complete each part of the test.

The effect of demographic variables on TMT performance has been found for age (Backman et al., 2004), education and IQ (Steinberg, Bieliauskas, Smith, & Ivnik, 2005), and ethnicity/culture (Manly et al., 1998). Gender has been found to have little impact on test performance (Hester, Kinsella, Ong, & McGregor, 2005). As a result of the test's popularity and the different demographic variables that impact performance, many normative studies have been done (Strauss et al., 2006). Recently Heaton, Miller, Taylor and Grant (2008) provided norms that adjust for age, education, gender, and race (Caucasian and African American) based on a sample of over 1,000 adults between the ages of 20 and 85 years.

Test-retest reliability with the TMT has varied depending on the age of participants and type of sample (e.g., clinical, non-clinical), though for the most part it has been found to be adequate (Strauss et al., 2006). Test-retest reliability has been stronger for Part B, with one study using 384 normal adults reporting coefficients of .79 for Part A and .89 for Part B (Dikmen, Heaton, Grant, & Temkin, 1999). Practice effects seem to be more significant when the retest interval is shorter (Basso, Bornstein, & Lang, 1999). In terms of validity, Part A and Part B correlate moderately well (Heilbronner, Henry, Buck, Adams, & Fogle, 1991), which has been taken to suggest they measure slightly different functions (Strauss et al., 2006). Part B has been found to correlate with other tests of attention and visuomotor scanning such as the Digit Symbol Test and the Symbol-Digit Modalities Test (Shum, McFarland, & Bain, 1990), and with the cognitive

flexibility aspect (perseverative errors) of the WCST (Kortte, Horner, & Windham, 2002).

The TMT, in particular Part B, has been recommended as a useful indicator of neurological integrity (Reitan & Wolfson, 2004). It has also been found to be sensitive to closed-head injury, with TMT completion times increasing with the severity of the injury (Des Rosiers & Kavanagh, 1987; Martin, Hoffman, & Donders, 2003). Part B of the TMT has often been used as a measure of executive functioning in research using TBI samples (Hanlon et al., 2010; Wood & Liossi, 2007).

Symbol Digit Modalities Test (SDMT)

The SDMT was created to screen for cerebral dysfunction and tests divided attention, visual scanning and tracking, and motor speed (Smith, 1991). The test can be administered in a written or oral format, and it consists of a one-page form with a coding key at the top containing nine abstract symbols that are each paired with a number. Below the coding key are several rows of boxes containing one of the abstract symbols in the top half and a blank box in the bottom half. The subject is instructed to fill in the number that corresponds to the symbol in the blank space as quickly and accurately as possible. There are several practice items, and then the subject has 90 seconds to complete as many items as possible (Strauss et al, 2006). The SDMT yields a total score based on the number of correct items, and scores that fall 1.5 *SD* below the mean or more are considered to be suggestive of cerebral dysfunction (Smith, 1991).

Several demographic factors have been found to impact performance on the SDMT including age, education level, and IQ (Strauss et al., 2006). Some research has suggested that gender also has an impact (Jorm, Anstey, Christensen, & Rodgers, 2004),

though other studies have found no difference (Gilmore, Royer, & Gruhn, 1983). Level of acculturation in an African American sample was found to affect scores on the written version (Kennepohl, Shore, & Nabors, 2004). Others have reportedly found an ethnicity effect on SDMT scores, although their results should be interpreted with caution as their sample contained a small portion of non-white participants (Uchiyama et al., 1994). More recently, Sheridan and colleagues (2006) found that age, education, gender, and income groupings did not have an impact on SDMT performance. The normative sample for the SDMT consisted of 1307 neurologically normal adults between the ages of 18 and 78 years. Age and education were reported but gender and race/ethnicity were not specified (Smith, 1991). These norms have been criticized for being outdated and for being drawn from an apparent convenience sample collected in a non-standardized fashion (Strauss et al., 2006). Updated norms have been developed for the written form that provide distinctions based on IQ and education from a sample of more than 3,000 homosexual and bisexual HIV-seronegative men (Uchiyama et al., 1994), as well as updated gender-specific norms for the oral version (Jorm et al., 2004).

The SDMT has been found to have good test-retest reliability for both the written ($r = .80$) and oral ($r = .76$) versions (Smith, 1991). The written and oral versions of the SDMT are highly correlated, though individuals tend to have higher scores on the oral version (Yeudall, Fromm, Reddon, & Stefanyk, 1986; Strauss et al., 2006). It has also been found to correlate with the Wechsler Digit Symbol/Coding Subtest (Morgan & Wheelock, 1992), though scores on the SDMT tend to be lower. The SDMT is more difficult than the Digit Symbol task because the key does not have the same internal structure (Strauss et al., 2006). In clinical studies, the SDMT has been found to be

extremely sensitive to brain insult and has become a widely used test of attention in the standard evaluation of several clinical populations including TBI (Strauss et al., 2006). Many studies have looked at use of the SDMT with TBI populations and have found it to successfully distinguish between individuals with TBI and controls (Bate, Mathias, & Crawford, 2001) and to predict changes in level of functioning in recovery (Hammond et al., 2004).

Grooved Pegboard

The Grooved Pegboard task is a test of hand-eye coordination and motor speed and is used to assess motor impairment (Matthews & Klove, 1964). The test includes a metal board with 25 holes that have randomly positioned slots. There is a well at the top of the board, into which the examiner places several identical metal pegs. The pegs are round with a ridge on one side, and they must be manipulated to fit into the various holes in the board. The examinee is instructed to place the pegs into the board as quickly as possible, one at a time, using only one hand. They fill the rows from left to right and top to bottom when using their right hand and from right to left and top to bottom when using their left hand. The examinee always begins with the dominant hand (Strauss et al., 2006). The test produces two scores based on the amount of time it takes the examinee to fill the board with each hand.

Age has been found to impact performance on the Grooved Pegboard task, and dominant hand performance is typically faster than non-dominant (Heaton et al., 2008). Some research has indicated that there are gender and education effects (Ruff & Parker, 1993), while other research has found little or no effect in these areas (Heaton et al., 2008). The influence of race/ethnicity has not been reported (Strauss et al., 2006).

Recently Heaton and colleagues (2008) provided norms that adjust for age, education, gender, and race (Caucasian and African American) that are based on a sample of over 1,000 adults between the ages of 20 and 85 years.

Research has demonstrated marginal to high test-retest reliability in non-clinical adult samples (Dikmen et al., 1999; Ruff & Parker, 1993), and repeated trials during the same testing session show that performance improves after the first trial (Schmidt, Oliveira, Rocha, & Abreu-Villaca, 2000). In terms of validity, the Grooved Pegboard task has been found to be more closely related to Finger Tapping than to Grip Strength and has been found to correlate modestly with tapping speed on the Finger Tapping task (Schear & Sato, 1989; Corey, Hurley, & Foundas, 2001). The test has been found to be sensitive to lateralized impairment (Lezak et al., 2004). No research looking at its utility with TBI samples was found, though it has been used as a measure of motor slowing in TBI research studies (Millis et al., 2001; Ashman et al., 2008).

Procedures

As described above, the data for the current study were collected as part of two multi-site research projects conducted in federal prisons: the MHPP and the TBIQ study.

MHPP Procedures

The sample for the MHPP consisted of 2,221 men and 634 women drawn from 14 federal prison sites across 3 security levels, located in five different geographic regions. The study was approved through the national research review board for the Federal BOP. Each institution had an on-site research coordinator and all the coordinators received standardized training for how to identify and enroll inmates in the study. All inmates entering a federal prison go through a psychology services intake screening process, and

the sampling for the MHPP was coordinated with these intakes at each participating site. Inmates who consented to participate filled out several self-report measures along with the standard intake documents. The measures administered included the GAMA, the Buss-Perry Aggression Questionnaire – Short Form (BPAQ-SF), the Coolidge Neuropsychological Dysfunction Scale (NDS), the Levenson Psychopathy Scale, and the Psychological Assessment Inventory (PAI).

Administrative data were collected from the PSIQ, information drawn from the PDS, and SENTRY. The Office of Research and Evaluation of the BOP provided SENTRY data after they were provided with identification numbers for all inmates participating in the study. Four independent coders were trained to code data from PSIs onto the PSI-Coding Form (PSI-CF), and they were trained to achieve at least 80% reliability before they began coding data (Diamond et al., 2008; Magaletta et al., 2009).

TBIQ Procedures

The TBIQ study was CDC funded and recruited participants from six federal prison sites that were chosen to ensure women were represented in the study and to minimize travel costs related to gathering the interview data. Four sites housed male inmates (two minimum, one medium, and one maximum) and two sites housed minimum-security female inmates. All inmates in these six facilities who had previously participated in the MHPP were approached to participate in the TBIQ study, and 256 out of the 308 inmates who were approached agreed to participate yielding a response rate of 73%. The final sample consisted of 225 inmates due to some of the consenting inmates being released or transferred prior to participating.

The researchers created a standardized training manual and all interviewers for the project went through two days of training. The majority of interviewers were graduate students and graduate assistants and one was a retired BOP psychologist. The interviewers were given an overview of the literature on TBI as well as a description of the project design and objectives. They were also trained on how to conduct the interviews and record interview information in a standardized format. A neuropsychologist trained the principal investigator and the project director on the administration and scoring procedures for the neuropsychological assessment battery. After receiving this training they trained the interviewers to administer these tests.

After interviewers began conducting field interviews, the principle investigator sat in on one to two days of their interviews and evaluated the interviewer's work using a standardized procedure. The interviewers were provided with feedback based on the evaluation and were subject to further re-training based on the evaluation. The field interviews began with completion of an informed consent and confidentiality agreement. After consent was obtained, several measures were administered in a pre-determined order including the Neurobehavioral Rating Scale – Revised, the Hopkins Verbal Learning Test – Revised, the Trail Making Test, the Grooved Pegboard task, the Wisconsin Card Sorting Test, the Symbol Digit Modalities Test, the CLOX, the Barratt Impulsiveness Scale, the CES-D, and the TBIQ. The TBIQ was administered last to avoid contamination by the interviewer having knowledge of their history of TBI before administering the neuropsychological measures.

The interviewers were instructed to conduct a field edit of their interviews shortly after completing them in order to ensure that all required information was complete. After

completion of their first interview, the principal investigator or the project director edited and reviewed the interview paperwork and provided feedback to the interviewer. All completed interviews were sent to the project headquarters within one workday where they could be stored securely. All participants had been assigned a number, and de-identified data were entered into a database along with prior data collected from the MHPP study.

Research Variables

The variables in the current study were operationalized as follows:

1. Intelligence Quotient (IQ) – IQ standard score on the GAMA
2. Executive Functioning – total number of categories achieved on the WCST-64, total number of perseverative errors on the WCST-64, and total score for Trails B
3. Verbal memory – total recall, delayed recall, percent retention, and recognition scores on the HVLTR
4. Attention – total score on the SDMT test, and total score for Trails A
5. Motor skills – total scores for both trials of the Grooved Pegboard task
6. Traumatic brain injury severity level – individuals were grouped by their most severe injury for the hypotheses that took severity level into account
 - a. No TBI – no reported history of head injury incident on the TBIQ
 - b. Mild TBI – In accordance with the CDC criteria (2003), a reported head injury with associated LOC of 30 minutes or less, and/or PTA of less than 24 hours
 - c. Moderate/Severe TBI – the two severity levels are grouped together because no clear definition for moderate TBI, aside from use of the GCS

score, was cited in the literature. These injuries will consist of a reported head injury with associated LOC of at least one hour and/or PTA for 24 hours or more

CHAPTER FOUR: RESULTS PRELIMINARY ANALYSIS

The study data were entered into IBM SPSS Statistics 19 software (IBM, 2011). The structural equation model was tested using *Mplus*, version six statistical analysis program (Muthen & Muthen, 2010). Preliminary examination of the data included assessment of normality, outlier analysis, and descriptive statistics. These procedures are described in greater detail below.

Inspection for Questionable and Missing Values

After being entered into SPSS, the data were initially examined via visual inspection by using the Explore feature in SPSS. No questionable values were detected, though a number of missing cases were identified. One suggested rule of thumb regarding missing data is that less than 10% for an individual case or observation can generally be ignored (Hair et al., 2006). One case was deleted because it was missing the majority of the data for that individual. No other cases were deleted due to missing, invalid, or questionable data.

Assessment of Normality

An assessment of normality is relevant to the current study given that structural equation modeling is based on analysis of covariance, and that kurtosis affects tests of variance and covariance. Curran, West, and Finch (1996) suggest that kurtosis index values equal to or greater than seven and skewness indexes equal to or greater than two indicate non-normality. Two variables had skewness and kurtosis index values outside the suggested range (disciplinary infractions SI = 2.135, std. error = .163, KI = 6.746, std. error = .324; number of psychological services used SI = 3.438, std. error = .163, KI =

16.255, std. error = .324). One recommendation for addressing a positive skew is to add a constant to the scores, making the lowest value 1.00, and use the square root function ($X^{1/2}$) to transform the data (Kline, 2011). This method was used with both skewed variables to bring their distribution closer to normality for use in the current analysis (disciplinary infractions $X^{1/2}$ SI = 1.216, std. error = .163, KI = 1.338, std. error = .324; number of psychological services used $X^{1/2}$ SI = 1.660, std. error = .163, KI = 3.654, std. error = .324).

Assessment for Outliers

Outliers were initially assessed via graphical visual inspection. Hair and colleagues (2006) suggest that the threshold for univariate outliers with larger sample sizes fall within four standard deviations of the mean. One Symbol Digit Modalities Test (SDMT) score fell outside of this range and the case was examined visually. The score appeared to be an outlier at both the individual level (i.e., most of the individual's performance was average, while this score was more than 4 SDs above the mean) and at the variable level. Descriptive statistics were run both with and without the score and it was found to have a large impact on several statistics. It was determined that the score should be left out of the analyses. In addition, Mahalanobis distance (D^2) for each case was computed to detect multivariate outliers. The Mahalanobis statistic measures the distance between observed scores from the centroid of all scores in standard deviation units (Kline, 2011). Any case with a D^2 value exceeding the critical chi-squared value (e.g., $p < .001$) would be deemed an outlier and excluded from further analysis. A review of D^2 values indicated there were no multivariate outliers.

Assessment of Collinearity

To assess that the data met the assumption of collinearity, scatterplots were visually inspected to look for collinearity among variables. Kline (2011) suggests screening for extreme collinearity prior to conducting SEM analysis by calculating the squared multiple correlation (R^2_{smc}) between each variable and all the others in the model. Any criterion value with an R^2_{smc} value $> .90$ would suggest extreme collinearity. This screening was done by running one multiple regression for each variable and identifying all others as predictors. None of the model variables exceeded the recommended R^2_{smc} value, as demonstrated below in Table 4.1.

Table 4.1

Squared Multiple Correlation (R^2_{smc}) for Each Predictor Variable

Predictor Variable	(R^2_{smc})
IQ	0.315
Education	0.210
TBI Severity	0.046
Substance Abuse History	0.100
WCST Categories	0.547
Perseverative Errors	0.534
Trails B	0.237
Disciplinary Infractions	0.104
Psych Services Contacts	0.015

Primary Analyses

Neuropsychological Test Norms

The Revised Comprehensive Norms for an Expanded Halstead-Reitan Battery (Heaton et al., 2008), which are disaggregated based on gender, age, level of education, and race (African American or Caucasian) were used to determine standardized scores on

the Trail-Making Test and the Grooved Pegboard task. The norms provided in the current edition of test manuals for the GAMA, HVLT-R, WCST-64 and the SDMT were used to determine standardized scores on these measures. When comparing standardized scores to normative data, scores that fall within one standard deviation above or below the mean are considered in the broad average range and are not impaired (T score $M = 50$, $SD = 10$; Standard score $M = 100$, $SD = 15$) (Lezak, 2004). Heaton and colleagues (2004) describe the following categories for qualitatively labeling test scores: above average (T score ≥ 55), average (T scores 45-54), below average (T scores 40-44). These categories were used to describe the sample performance on test measures when addressing the research questions and hypotheses.

The research questions and hypotheses proposed in the current study were addressed as follows:

Research Question 1. What is the level of neurocognitive functioning in the domains of IQ, executive functioning, verbal memory, attention, and motor skills for this sample?

As displayed in Table 4.2 below, the mean performance for the sample on all but three tests fell in the average range when compared to the normative group.

Table 4.2

Range and Means (Standard Deviations) of Test Scores			
	Range		Mean (SD)
	Minimum	Maximum	
GAMA IQ Standard Score (N=224)	61	131	92.26 (12.23)
WCST Perseverative Error T Score (N=224)	19	64	44.44 (8.28)
WCST Categories Completed (N=224)	0	5	2.79 (1.41)
Trails A T Score (N=223)	18	87	47.09 (11.05)
Trails B T Score (N=219)	20	80	48.62 (10.85)
SDMT Standard Score (N=223)	35	137	91.15 (20.91)
Pegs Dominant T Score (N=223)	17	76	45.10 (10.02)
Pegs Nondominant T Score (N=224)	17	74	45.47 (9.29)
HVLT-R- Total Score T Score (N=224)	20	66	40.60 (10.72)
HVLT-R- Delayed Recall T Score (N=224)	20	61	42.65 (11.08)
HVLT-R- % Retention T Score (N=224)	20	80	48.54 (12.09)
HVLT-R- Recognition T Score (N=220)	20	60	49.50 (9.92)

Note: GAMA = General Ability Measure for Adults, WCST = Wisconsin Card Sorting Test, SDMT = Symbol Digit Modalities Test, HVLT-R = Hopkins Verbal Learning Test

The majority of test scores were within the average range when compared to the normative sample across all measures of central tendency. The mean and median IQ scores were in the average range (standard score, $M = 92.26$, $median = 91.00$), though the mode was in the below average range ($mode = 87$). Executive functioning was primarily in the average range across all measures of central tendency on all three measures, as displayed in Table 4.3 below. The one exception was the mean WCST perseverative errors T score, which was below average.

Table 4.3

Average Scores on Executive Functioning Measures			
	Mean	Median	Mode
WCST Perseverative Error T Score (N=224)	44.44	45	47
WCST Categories (N=224)	2.79	3	4
Trails B T Score (N=219)	48.62	48	48

Note: WCST = Wisconsin Card Sort Test

In terms of verbal memory and learning, when compared to the normative data, the sample demonstrated immediate and delayed recall in the below average range. Retention and recognition discrimination were in the average range, as displayed in Table 4.4 below. Of note, the modal score for total recall was a T score of 20 (N = 14, 6.3% of the sample) which is in the severely impaired range.

Table 4.4
Measures of Central Tendency for Memory Measures

	Mean	Median	Mode
HVLT-R Total Score T Score (N=224)	40.6	41.5	20
HVLT-R Delayed Recall T Score (N=224)	42.65	44	44
HVLT-R % Retention T Score (N=224)	48.54	49	55
HVLT-R Recognition Disc. T Score (N=220)	49.5	51	58

Note: HVLT-R = Hopkins Verbal Learning Test - Revised

Performance on measures of attention and motor speed was in the average range across most measures of central tendency, as follows in Table 4.5 below.

Table 4.5
Measures of Central Tendency for Attention and Motor Measures

	Mean	Median	Mode
Trails A T Score (N=223)	47.09	47	43
SDMT Standard Score	91.15	92	83
Pegs Dominant T Score (N=223)	45.1	44	54
Pegs Nondominant T Score (N=224)	45.47	45	43

Note: SDMT = Symbol Digit Modalities Test

Research Hypothesis 1. Individuals reporting more severe head injuries (moderate, severe) will show greater deficits in executive functioning than those reporting mild head injuries or no head injuries.

After determining that the three measures of executive functioning correlated (see Table 4.6), a MANOVA was run to look for differences in executive functioning between the three groups (no head injury, mild head injury, moderate/severe head injury).

Standard scores were used for Trails B and WCST perseverative errors. Box's test of equality of covariance matrices was not significant ($F_{(12,30262)} = .546$, sig. = .886) indicating the data met the MANOVA assumption of homogeneity of variance. Levene's test, shown in Table 4.7 below, was also nonsignificant for all three measures of executive functioning, indicating the error variance was equal across all three groups.

	WCST Perseverative Errors T Score	Trails B T Score
WCST Categories Complete (N=224)	.678** Sig.(2-tailed) .000	.270** Sig.(2-tailed) .000
WCST Perseverative Errors T Score	-	.270** Sig.(2-tailed) .000

** Correlation is significant at the .01 level (2-tailed)

Table 4.7
Levene's Test of Equality of Error Variances^a

	F	df1	df2	Sig.
Trails B T score	.617	2	216	.541
WCST Psv Error T score	.342	2	216	.711
WCST Categories Complete	1.471	2	216	.232

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + TBI

Mean scores on each of the three executive functioning measures, separated by TBI severity level, are presented in Table 4.8 below. Table 4.9 below displays the results of the MANOVA. Four multivariate tests were used to detect differences in executive functioning between the different levels of TBI severity, and all four tests yielded

nonsignificant results. These results indicate there was no significant difference in executive functioning across the different levels of TBI injury severity.

Table 4.8

Mean Test Scores by TBI Severity				
TBI		Mean	Std. Deviation	N
Trails B T-score	no head injury	49.64	9.87	28
	mild head injury	49.43	10.72	69
	mod/severe head injury	47.93	11.17	122
	Total	48.62	10.85	219
WCST Categories Complete	no head injury	3.04	1.29	28
	mild head injury	2.84	1.48	69
	mod/severe head injury	2.70	1.40	122
	Total	2.79	1.41	219
WCST Psv Errors T-score	no head injury	44.50	8.35	28
	mild head injury	46.29	8.83	69
	mod/severe head injury	43.39	7.86	122
	Total	44.44	8.31	219

Table 4.9

MANOVA - Executive Functioning Measures Between TBI Severity Group Comparison

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.971	2384.309 ^a	3.000	214.000	.000	.971
	Wilks' Lambda	.029	2384.309 ^a	3.000	214.000	.000	.971
	Hotelling's Trace	33.425	2384.309 ^a	3.000	214.000	.000	.971
	Roy's Largest Root	33.425	2384.309 ^a	3.000	214.000	.000	.971
TBI	Pillai's Trace	.042	1.523	6.000	430.000	.169	.021
	Wilks' Lambda	.959	1.524 ^a	6.000	428.000	.169	.021
	Hotelling's Trace	.043	1.524	6.000	426.000	.169	.021
	Roy's Largest Root	.036	2.574 ^b	3.000	215.000	.055	.035

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept + TBI

Research Hypothesis 2. Individuals with lower cognitive reserve (i.e., substance abuse history, TBI history, lower IQ, lower educational attainment) will show greater deficits in executive functioning than those with higher cognitive reserve.

To test this hypothesis, multiple regression was used to identify which cognitive reserve factors predicted executive functioning outcomes. Before this procedure was conducted, an initial examination of data indicated there were correlations between all pairs of variables, as displayed in Table 4.10 below. However, the correlations between the predictor variables (i.e., substance abuse, TBI severity, IQ, and educational attainment) did not indicate extremely high multicollinearity, which would be indicated by Pearson r values greater than .9 (Warner, 2008).

Table 4.10
Correlations Between Cognitive Reserve and Executive Functioning Variables

		Education	Trail B Tscore	WCST Categories	IQStd	TBI Severity	AODA History	WCST Psv Err T Score
Education	Pearson Correlation	1	.069	.206**	.235**	.092	-.066	-.082
	Sig. (2-tailed)		.312	.002	.000	.171	.325	.224
	N	224	219	224	224	224	222	224
Trail B T score	Pearson Correlation		1	.270**	.450**	-.068	.120	.270**
	Sig. (2-tailed)			.000	.000	.320	.076	.000
	N		219	219	219	219	219	219
WCST Categories	Pearson Correlation			1	.350**	-.073	.079	.678**
	Sig. (2-tailed)				.000	.276	.242	.000
	N			224	224	224	222	224
IQStd	Pearson Correlation				1	-.133*	.045	.322**
	Sig. (2-tailed)					.047	.501	.000
	N				224	224	222	224
TBI Severity	Pearson Correlation					1	.003	-.101
	Sig. (2-tailed)						.962	.133
	N					224	222	224
AODA History	Pearson Correlation						1	.087
	Sig. (2-tailed)							.195
	N						222	222
WCST Perseverative Errors T Score	Pearson Correlation							1
	Sig. (2-tailed)							
	N							224

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

It is also recommended that graphs of the standardized residuals resulting from multiple regressions be analyzed for evidence that multivariate assumptions for regression are met. When these assumptions are satisfied by the data, the points in the plot should appear within a fairly uniform band from left to right, with most standardized residuals falling between -3 and +3 (Warner, 2008). Graphs of the standardized residuals

for each of the executive functioning measures are displayed in Figures 4.1 through 4.3 below and demonstrate that the assumptions for regression were reasonably satisfied by two of the three measures: Trails B scores and WCST perseverative error scores. The standardized residuals for the third measure (WCST categories) did not appear to be normally distributed around zero.

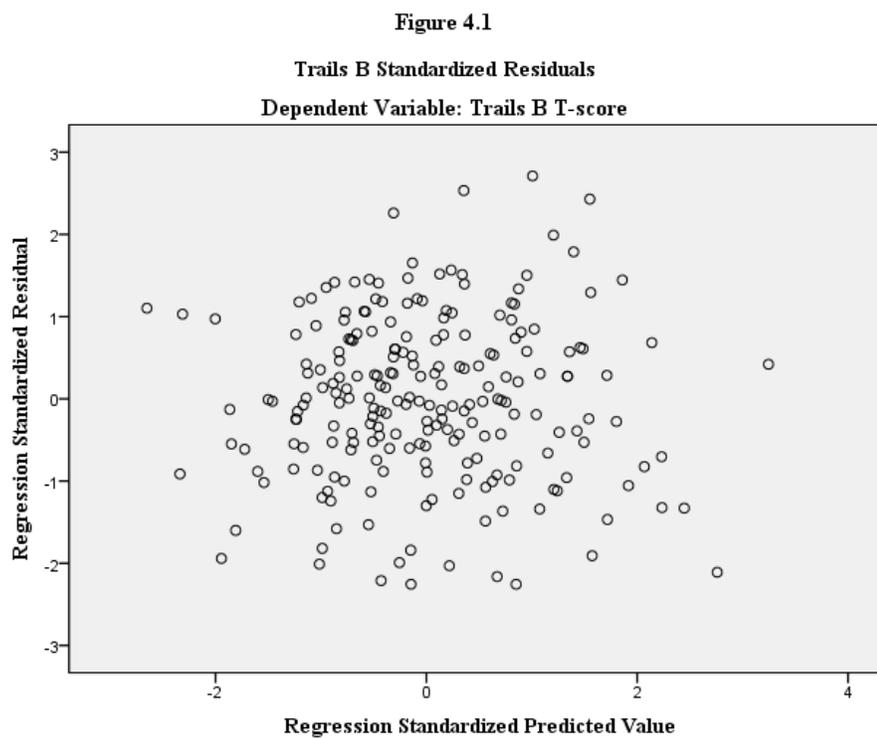


Figure 4.2

WCST Perseverative Errors Standardized Residuals
Dependent Variable: Perseverative Errors T score

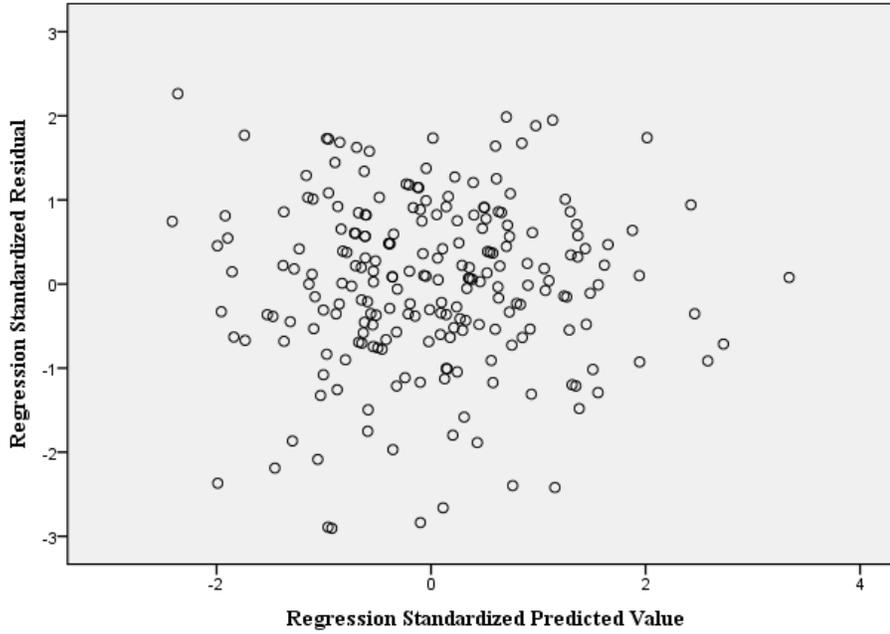
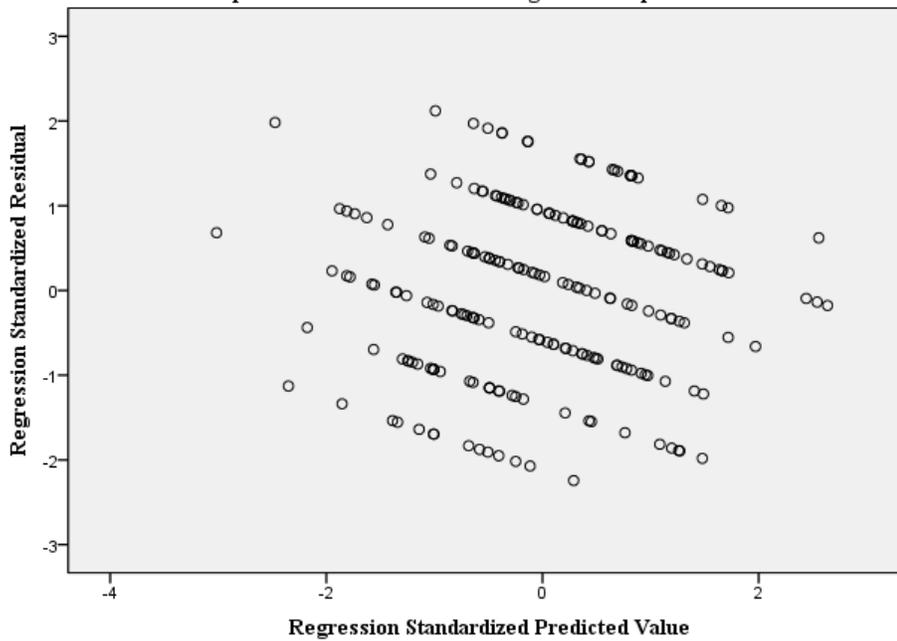


Figure 4.3

WCST Categories Completed Standardized Residuals
Dependent Variable: WCST Categories Completed



The results of the multiple regression analysis to predict Trails B performance from education, IQ, TBI severity, and substance abuse are shown in Table 4.11, and indicate that $R = .46$ and $R^2 = .21$. That is, when all four cognitive reserve variables were used as predictors, about 21% of the variance in Trails B performance could be predicted. The adjusted R^2 was .20. The overall regression was statistically significant, $F_{(4, 214)} = 14.49, p < .001$. IQ was significantly predictive of Trails B performance when the other variables were controlled, $t_{(214)} = 7.13, p < .001$. The positive slope for IQ as a predictor of Trails B performance indicated that there was about a .40 increase in the Trails B T score for each 1 point increase in IQ, controlling for education, substance abuse, and TBI severity. The squared semipartial that estimated how much variance in Trails B performance was uniquely predictable from IQ was $sr^2 = .19$. About 19% of the variance in Trails B was uniquely predictable from IQ (when education, substance abuse, and TBI severity were controlled).

Education ($t_{(214)} = -.453, ns$), substance abuse ($t_{(214)} = 1.55, ns$), and TBI severity ($t_{(214)} = -.102, ns$) were not significantly predictive of Trails B performance when their counterpart predictor variables were statistically controlled. The conclusion from this analysis is that the original zero-order correlation between IQ and Trails B performance ($r = .45$ or $r^2 = .20$) was in part accounted for by the other predictors. However, when the other predictors were statistically controlled, IQ still uniquely predicted 19% of the total 21% of the variance in Trails B that can be explained by all the predictors.

Table 4.11

Results of Standard Multiple Regression to Predict Trails B (Y) from Education (X_1), IQ (X_2), Number of TBIs (X_3), and Substance Abuse (X_4)							
<i>Variables</i>	<i>Trails</i>				<i>b</i>	β	st^2_{unique}
	<i>B</i>	<i>Education</i>	<i>IQ</i>	<i>TBI</i>			
Education	0.07				-0.12	-0.03	0.00
IQ	0.45**	0.24**			0.41***	0.46	0.19
TBI Severity	0.09	0.09	0.26**		-0.14	-0.04	0.00
Substance Abuse	0.12	-0.07	0.05	0.12	2.28	0.10	0.01
				Intercept	= 10.92		
Means	48.62	10.73	92.26	3.63			
SD	10.85	2.70	12.24	3.04			
						$R^2 = 0.21$	
						$R^2 \text{ adj} = 0.20$	
						$R = 0.46***$	

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

For the overall multiple regression to predict Wisconsin Card Sorting Test (WCST) perseverative error performance from education, IQ, TBI severity, and substance abuse, $R = .36$ and $R^2 = .13$. That is, when all four cognitive reserve variables were used as predictors, about 13% of the variance in WCST perseverative error performance could be predicted. The adjusted R^2 was .12. The overall regression was statistically significant, $F_{(4, 217)} = 8.21$, $p < .001$. Complete results for the multiple regression are presented in Table 4.12 below. IQ was significantly predictive of WCST perseverative error performance when the other variables were controlled: $t_{(217)} = 5.23$, $p < .001$. The positive slope for IQ as a predictor of WCST perseverative error performance indicated that there was about a .23 increase in the WCST perseverative error T score for each one point increase in IQ, controlling for education, substance abuse, and TBI severity. To clarify, a higher perseverative errors T score means the person made fewer

errors. The squared semipartial that estimated how much variance in WCST perseverative error performance was uniquely predictable from IQ was $sr^2 = .11$. About 11% of the variance in WCST perseverative errors was uniquely predictable from IQ (when education, substance abuse, and TBI severity were controlled).

Education was also significantly predictive of WCST perseverative error performance when the other variables were controlled: $t_{(217)} = -2.18, p < .05$. The negative slope for education as a predictor for perseverative error T score (note: a higher T score equals fewer errors) indicated that there was a .5 point drop in the perseverative error T score (indicating more errors) for each one year increase in education. These findings are the reverse of what would be expected. Approximately 2% of the variance in WCST perseverative errors was uniquely predictable from education ($sr^2 = .02$) when all other predictors were controlled.

Substance abuse ($t_{(217)} = .980, ns$) and TBI severity ($t_{(217)} = -.703, ns$) were not significantly predictive of WCST perseverative error performance when their counterpart predictor variables were statistically controlled. The conclusion from this analysis is that the original zero-order correlation between IQ and WCST perseverative error performance ($r = .32$ or $r^2 = .10$) was in part suppressed by the other predictor variables. However, when education and the other predictors were statistically controlled, IQ still uniquely predicted approximately 11% of the total 13% of the variance in WCST perseverative error performance that can be explained by all the predictors.

Table 4.12

Results of Standard Multiple Regression to WCST Perseverative Errors (Y) from Education (X_1), IQ (X_2), Number of TBIs (X_3), and Substance Abuse (X_4)

Variables	WCST <i>Psv</i> Errors				<i>b</i>	β	st ² _{unique}
	Education	IQ	TBI				
Education	-0.82				-0.46*	-0.15	0.02
IQ	0.32**	0.24**			0.24***	0.36	0.12
TBI Severity	0.06	0.09	0.26**		-0.08	-0.03	0.00
Substance Abuse	0.08	-0.07	0.05	0.12	0.23	0.08	0.01
				Intercept =	-1.64		
Means	44.45	10.73	92.26	3.63			
SD	8.29	2.70	12.24	3.04			
						$R^2 = 0.13$	
						$R^2 \text{ adj} = 0.11$	
						$R = 0.36***$	

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

Finally, for the overall multiple regression to predict WCST categories completed from education, IQ, TBI severity, and substance abuse, $R = .40$ and $R^2 = .16$. That is, when all four cognitive reserve variables were used as predictors, about 16% of the variance in WCST completed categories could be predicted. The adjusted R^2 was .14. The overall regression was statistically significant, $F_{(4, 217)} = 10.113$, $p < .001$. Complete results for the multiple regression are presented in Table 4.13 below. IQ was significantly predictive of WCST categories completed when the other variables were controlled: $t_{(217)} = 4.70$, $p < .001$. The positive slope for IQ as a predictor of WCST categories completed indicated that there was about a .04 increase in the WCST categories completed for each one point increase in IQ, controlling for education, substance abuse, and TBI severity. The squared semipartial that estimated how much variance in WCST categories

completed was uniquely predictable from IQ was $sr^2 = .09$. About 9% of the variance in WCST categories was uniquely predictable from IQ (when education, substance abuse, and TBI severity were controlled).

Education was also significantly predictive of WCST categories performance when the other variables were controlled: $t_{(217)} = 2.59, p < .05$. The positive slope for education as a predictor for WCST categories completed indicated that there was a .1 increase in categories completed for each one year increase in education. Approximately 3% of the variance in WCST categories completed was uniquely predictable from education ($sr^2 = .026$) when all other predictors were controlled.

Substance abuse ($t_{(217)} = 1.22, ns$), and TBI severity ($t_{(217)} = -.93, ns$) were not significantly predictive of WCST categories completed when their counterpart predictor variables were statistically controlled. The conclusion from this analysis is that the original zero-order correlation between IQ and WCST categories completed ($r = .35$ or $r^2 = .12$) was in part accounted for by education. Looking at it another way, the original zero-order correlation between education and WCST categories completed ($r = .21$ or $r^2 = .04$) was largely accounted for by IQ. As with the other measures of executive functioning, when education and the other predictors were statistically controlled, IQ still uniquely predicted the majority (9% of the total 16%) of the variance in WCST perseverative error performance that can be explained by all the predictors.

Table 4.13

Results of Standard Multiple Regression to WCST Categories (Y) from Education (X_1), IQ (X_2), Number of TBIs (X_3), and Substance Abuse (X_4)							
<i>Variables</i>	<i>WCST Categories</i>	<i>Educatio n</i>	<i>IQ</i>	<i>TBI</i>	<i>b</i>	β	sr^2_{unique}
Education	0.21**				0.08*	0.16	0.02
IQ	0.35**	0.24**			0.04***	0.32	0.09
TBI Severity	0.10	0.09	0.26**		0.00	0.00	0.00
Substance Abuse	0.08	-0.07	0.05	0.12	0.23	0.08	0.01
				Intercept =	-1.64		
Means	2.79	10.73	92.26	3.63			
SD	1.41	2.70	12.24	3.04			
						$R^2 =$	0.15
						$R^2 \text{ adj} =$	0.14
						$R =$	0.39***

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

When considering the results of all three multiple regressions together as they relate to the hypothesis, the cognitive reserve variables were able to predict scores on the executive functioning measures at a statistically significant level. Further, level of cognitive reserve and executive functioning performance were generally positively correlated, supporting the original hypothesis. Only one of the four cognitive reserve variables (IQ) was a consistent positive predictor of executive functioning performance, though education and substance abuse were significant predictors in some cases. In contrast to the hypothesis, level of education was slightly negatively related to perseverative error performance on the WCST, such that as education level decreased the T score for perseverative errors increased.

Research Hypothesis 3. Individuals with greater executive functioning deficits will exhibit more behavior problems during the first two years of the current incarceration.

This hypothesis was initially examined by calculating three Pearson's r correlations comparing the number of behavioral infractions incurred and the number of psychological services contacts to each of the three measures of executive functioning. The hypothesis was also more fully addressed through the structural equation model presented below. The six Pearson correlations are reported in Table 4.14 below. None of the correlations were significant.

Table 4.14

Correlations Between Institution Behavior Variables and Executive Functioning Measures

		Trails B T score	Psv Errors T score	WCST Categories	# Psych Svc	# Disc. Inf.
Number of Psych Svc Visits	Pearson Correlation	-.065	-.045	-.004	1	.023
	Sig. (2-tailed)	.338	.504	.957		.729
	N	219	224	224	224	224
Number of Disc. Infractions	Pearson Correlation	-.026	.100	.129	.023	1
	Sig. (2-tailed)	.707	.136	.053	.729	
	N	219	224	224	224	224

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

Finally, structural equation modeling was used to test the cognitive reserve theory and explore the relationships between cognitive reserve, executive functioning, and behavior in the institution. Measurement models were developed for cognitive reserve, executive functioning, and institutional behavior to form composites for these latent variables (Figures 4.4, 4.5 and 4.6 below). Three major relationships were posited in the conceptual model and are outlined below:

1. Cognitive reserve and executive functioning will be correlated, and greater cognitive reserve will be positively related to greater executive functioning.

2. Greater cognitive reserve will be positively related to better institutional behavior (i.e., fewer behavioral infractions and psychological services contacts).
3. Executive functioning will mediate the relationship between cognitive reserve and institutional behavior.

Each of the latent variables was represented by multiple indicator variables, as described in Table 4.15 below.

Table 4.15
Latent Variables and Their Indicators

Latent variables	Measured variables (indicators of latent variables)
Cognitive Reserve	IQ (GAMA IQ score) Level of Education History of Substance Abuse (AODA) History of TBI, Severity Level of Most Significant Reported Injury
Executive Functioning	Wisconsin Card Sorting Test Perseverative Errors (T score) Wisconsin Card Sorting Test Categories Completed Trails B Performance (T score)
Institution Behavior	Number of Behavioral Infractions (within first 2 years) Number of Psychological Services Contacts (within first 2 years)

Figure 4.4 Cognitive Reserve Measurement Model

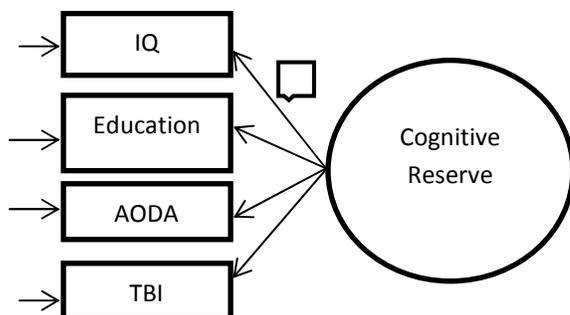


Figure 4.5 Executive Functioning Measurement Model

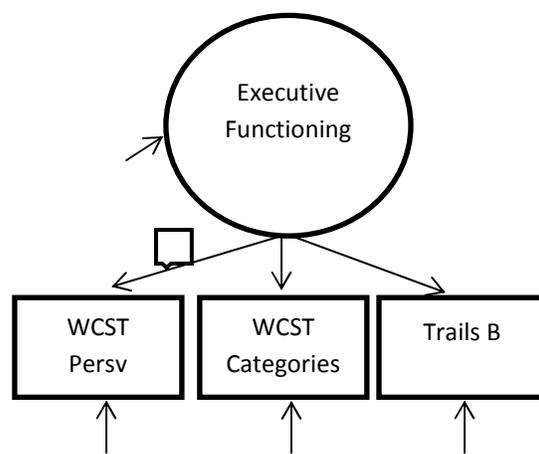
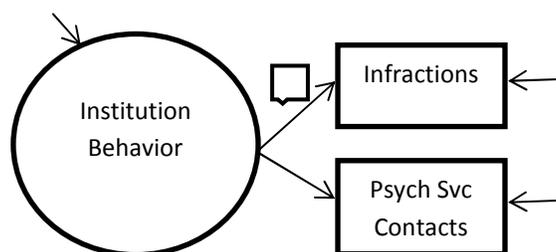


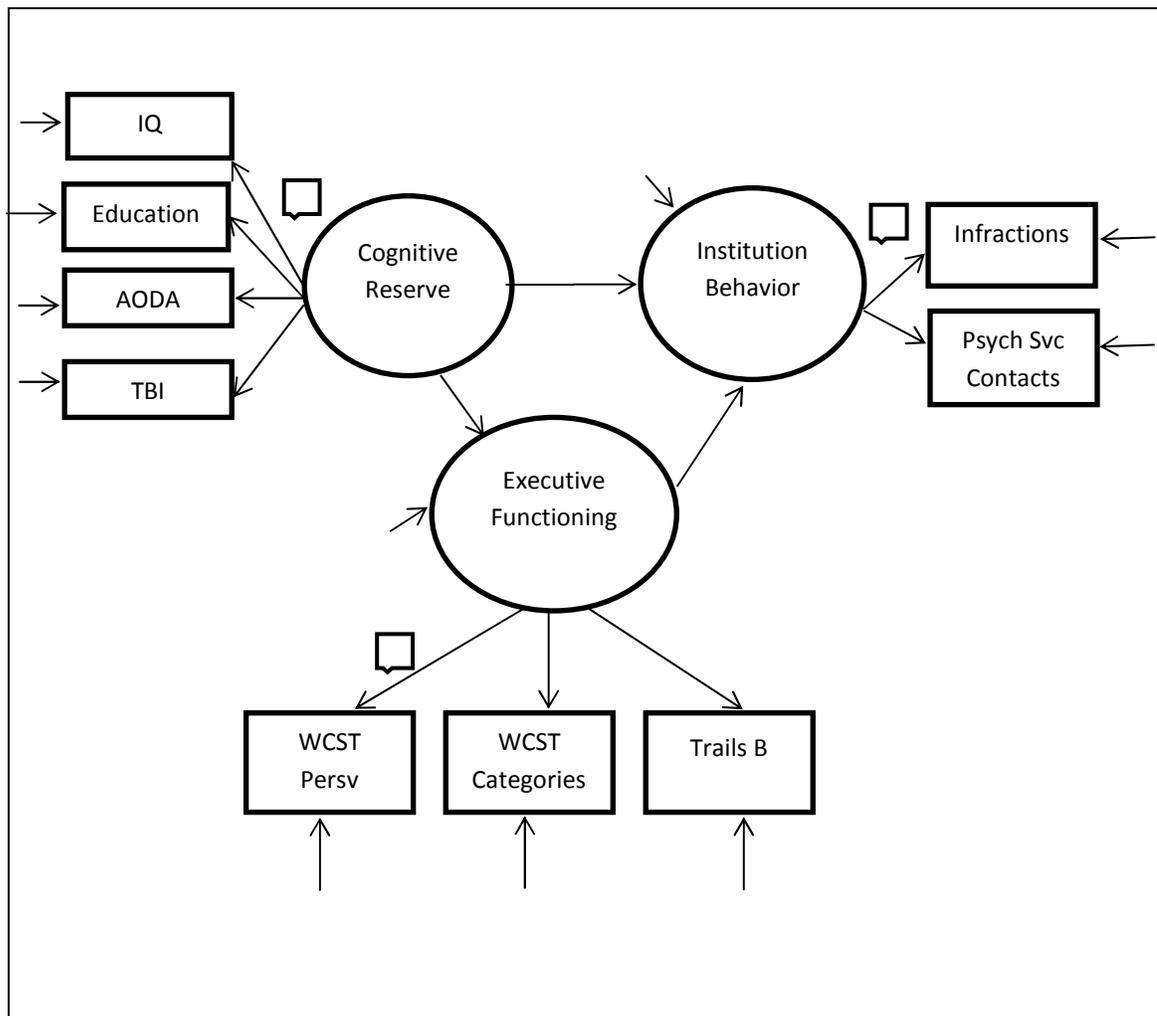
Figure 4.6 Institution Behavior Measurement Model



Model Specification

The statistical model that was initially tested (and then refined as appropriate) is presented below in Figure 4.7 using *Mplus* language. Squares represent observed variables and circles represent latent variables. The single-headed arrows pointed at each observed variable represent measurement error, and those pointed at endogenous latent variables represent residual error in the prediction of an unobserved variable. The callouts represent constrained factor loadings for scaling each latent variable. The statistical model includes nine observed variables (e.g., IQ score, WCST perseverations, institutional infractions), one exogenous variable (i.e., cognitive reserve), and two endogenous variables (i.e., executive functioning and institutional behavior).

Figure 4.7 Full Structural Equation Model in MPlus Language



Model Identification

The model included 54 unique elements (i.e., $(p(p + 1)/2)$, plus the observed variable intercepts that *Mplus* determines by default) and 29 estimable parameters. Therefore, the degrees of freedom (*df*) for the initial model were 25. The model met the necessary but not sufficient condition of overidentification. As indicated in Figure 4.7 above, one indicator from each latent variable was fixed to one to use as a reference variable for scaling purposes, which satisfied another identification requirement. The

model also met the minimum requirement of ≥ 2 indicators per factor required for models with ≥ 2 factors. Finally, the structural model was recursive because none of the measurement error terms were hypothesized to be correlated and all the causal effects were unidirectional (Kline, 2011).

Model Estimation – Testing the Measurement Model

Initial confirmatory factor analysis (CFA) using maximum likelihood (ML) estimation, the missing data option in *Mplus*, identifying the alcohol and other drug abuse (AODA) variable as categorical, and containing all three latent variables, returned an error result indicating no convergence. Review of the covariance matrix, as recommended by Muthen and Muthen (2010), revealed a range of sample variance values that was significantly beyond the recommended maximum of 10.0 and indicated the covariance matrix was ill scaled (Kline, 2011). An additional concern identified was that the two variables transformed using a nonlinear transformation (i.e., number of behavioral infractions and number of psychological services) were problematic because they were scaled differently than the other variables. The transformed versions of these variables were removed and replaced with the raw data. Based on the review of the original covariance matrix, Trails B, IQ, and number of psychological services were all linearly transformed by dividing each value by 10. These linear transformations brought the range of covariances from 66.42 down to 9.75, bringing it into an acceptable range.

A second CFA was run incorporating the new transformed variables and returned an error that the residual covariance matrix was not positive definite. The error stemmed from two Heywood cases (Kline, 2011) and indicated the model in its current form was not correct for the data. The variable IQ produced a negative residual (-.915) and the

institutional behavior latent variable produced a negative variance (-.006). An exploratory factor analysis (EFA) was run with only the cognitive reserve and executive functioning variables to determine if these latent variables could be revised to improve fit, prior to attempting to correct the issues with the institutional behavior variable. The EFA returned a two factor model with TBI severity level, IQ, education, and Trails B performance loading on one factor and WCST perseverative errors and total number of categories loading on a second factor, as demonstrated in Table 4.16 below. Substance abuse history did not load strongly on either factor.

Table 4.16

EFA with all Cognitive Reserve and Executive Functioning Variables		
	Geomin Rotated Loadings	
	1	2
	-	
TBI Severity	0.961	-0.07
IQ	0.707	-0.043
Education	0.549	-0.635
Trails B T score	0.531	0
WCST Psv T score	0.001	0.98
WCST Categories Completed	0.342	0.517
AODA	0.054	0.081

Conceptually, it was not entirely surprising that the three measures designed to capture executive functioning did not load on the same factor. As described in Chapter Three above, the WCST has inconsistently correlated with other measures of executive functioning because the tests are tapping into different abilities. While both the WCST and Trails B require cognitive flexibility, WCST is designed to test abstract concept

formation, set maintenance and shifting, and the ability to utilize feedback (Strauss et al., 2006). In contrast, the Trail Making Test performance is strongly related to processing speed and visuomotor tracking (Lezak et al., 2004). Theoretically, there is support for including Trails B performance as a component of cognitive reserve. In a recent theoretical paper, Satz, Cole, Hardy, and Rassovsky (2011) included processing speed as a component of cognitive reserve, based on existing literature that supports its role in cognitive reserve.

Model estimation – testing the revised measurement models for cognitive reserve and executive functioning.

A third CFA was run using the revised measurement model whereby education, IQ, TBI severity, and Trails B represented cognitive reserve, and WCST perseverative errors T score and WCST number of categories completed represented executive functioning (see figures 4.8 and 4.9 below).

Figure 4.8 Revised Cognitive Reserve Measurement Model

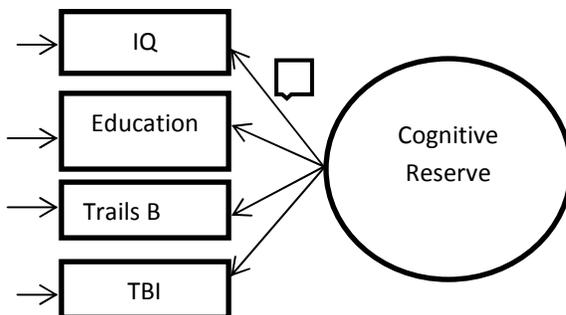
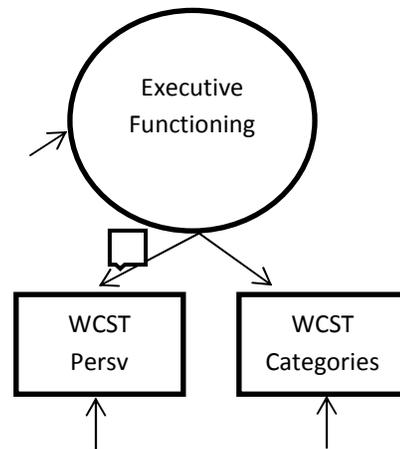


Figure 4.9 Revised Executive Functioning Measurement Model



Model fit was initially examined with a number of criteria including the chi-square test statistic (χ^2), Tucker-Lewis Fit Index (TLI), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). Results are displayed in Table 4.19 below (results in CFA #3 column). Other than SRMR, all indices of model fit fell outside of the recommended values and indicated a poor fit. As a measure of overall model fit, the χ^2 statistic is a measure of how much the implied (i.e., population) covariance matrix differs from the sample covariance matrix. The more the implied covariance differs from the sample covariance, the larger the χ^2 statistic will be. In SEM, statistical significance testing is driven by degrees of freedom. Well-fitting models are indicated when χ^2 approximates the degrees of freedom with a probability level $> .05$. Overall model fit for this model was unsatisfactory ($\chi^2 = 38.911$, $df = 8$, $p = .0000$). However, problems with the χ^2 statistic are widely acknowledged (Byrne, 2012; Kline, 2011). For this reason, model evaluation also involved the use of the additional goodness-of-fit statistics.

Model fit was further assessed via CFI and TLI. Both are commonly used indexes that compare the hypothesized model to the independence model, providing a measure of covariation. The CFI standard for superior fit is set at 0.95 (Hu & Bentler, 1999), and TLI is traditionally interpreted using the same criteria (Byrne, 2012). As such, the current results did not meet this criteria (CFI = .883, TLI = .78). In addition, Byrne (2012) acknowledges that RMSEA is an informative criterion for model fit that accounts for error approximation in the population. The RMSEA statistic provides output regarding degrees of freedom, which makes the index sensitive to the number of estimated parameters in the model. Values between 0.05 and 0.06 indicate good fit; values less than or equal to .08 indicate adequate fit, and values of .10 or higher indicate poor fit. The RMSEA value for the tested model indicated poor fit (RMSEA = 0.131). The SRMR was the only goodness-of-fit-index that fell within the recommended parameters (SRMR = .051), with SRMR values of approximately .05 or less indicating a good fit. The SRMR represents the average standardized residual derived from the fitting of the variance-covariance matrix. As such, it represents the average discrepancy between the observed sample and the hypothesized correlation matrices, so one can interpret the value obtained to mean that the model explains the correlations to within an average error of .051.

An assessment of individual parameter estimates indicated that TBI severity was unimportant to the model (estimate = -.102, SE = .055, $p = .063$). All other parameters had reasonable estimates and were statistically significant. A review of R^2 values for the observed variables indicated that TBI severity ($R^2 = .021$, $p = .335$) and education ($R^2 = .064$, $p = .090$) did not contribute significantly to the variance in the cognitive reserve

factor. Examination of the modification indices revealed that freely estimating the covariance between education and the two Wisconsin Card Sort Test (WCST) variables would significantly improve model fit.

A fourth CFA was run excluding TBI severity from the cognitive reserve factor and including the covariations between the education variable and each of the WCST variables. Goodness-of-fit statistics indicated the revised model substantially improved the fit of the model to the data, as displayed in Table 4.17 below (results in CFA #4 column). Overall model fit for this model as assessed with X^2 was satisfactory ($X^2 = 2.946$, $df = 2$, $p = .2292$). Model fit was further assessed via CFI and TLI and both indexes exceeded the superior fit threshold of .95 (CFI = .996, TLI = .982). The RMSEA value for the tested model indicated good fit (RMSEA = 0.046), as did the SRMR (SRMR = .022).

Table 4.17

Goodness of Fit Statistics for Confirmatory Factor Analyses		
	CFA #3	CFA #4
Chi-Square Test of Model Fit		
Value	38.91	2.95
Degrees of Freedom	8.00	2.00
P-value	0.00	0.23
Chi-Square Test of Model Fit for the Baseline Model		
Value	278.54	270.32
Degrees of Freedom	15.00	10.00
P-value	0.00	0.00
CFI/TLI		
CFI	0.88	1.00
TLI	0.78	0.98
Root Mean Square Error of Approximation (RMSEA)		
Estimate	0.13	0.05
90% Confidence Interval	.09 - .17	0 - .15
Probability RMSEA \leq .05	0.00	0.40
Standardized Root Mean Square Residual (SRMR)		
Value	0.05	0.02

Note: CFA #3 - initial CFA after measurement model was revised;
CFA #4 - final version of measurement model before testing full structural model

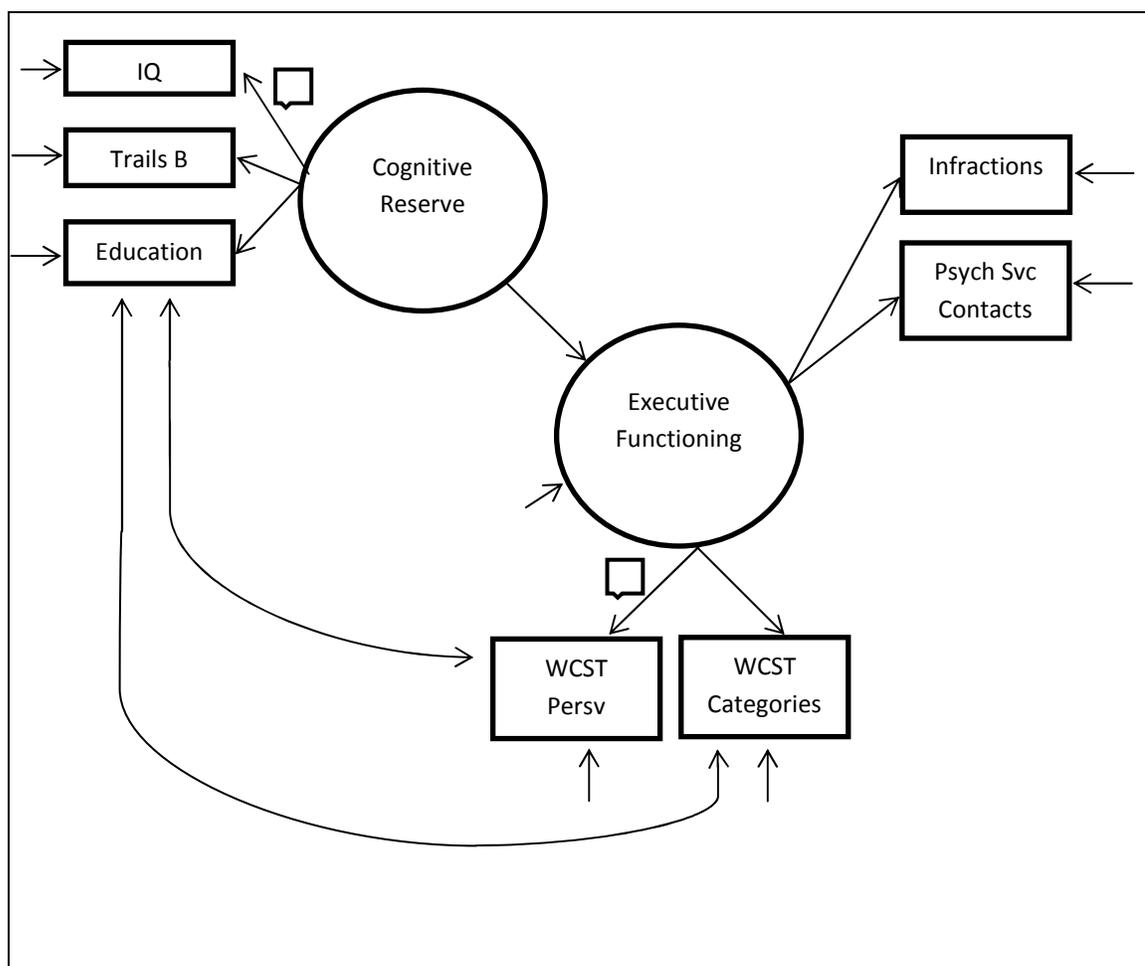
An assessment of individual parameter estimates indicated that all were significant except the covariance between education and WCST categories (estimate = .350, S.E. = .240, $p = .143$). A review of R^2 values for the observed variables indicated

that education ($R^2 = .067$, $p = .085$) still did not contribute significantly to the variance in the cognitive reserve factor. No further modification indices were suggested.

Model Estimation – Testing the Revised Structural Model

Based on the measurement model analyses described above, the revised structural model depicted in Figure 4.10 below was tested. The latent variable *institution behavior* was removed because the two indicator variables did not converge, though they were left in as manifest variables.

Figure 4.10 Revised Structural Model



The model was tested using MLR, a maximum likelihood method that is more robust to non-normality (Muthen & Muthen, 2010). The analysis returned an error that the residual covariance matrix was not positive definite. The error stemmed from one Heywood case (Kline, 2011) and indicated the model in its current form was not correct for the data. The variable IQ produced a negative residual (-.754).

The structural model was revised again by setting the WCST Perseverative Errors measurement error term at .3 (1 - .7) to reflect the reliability the measure has demonstrated in the literature. The model terminated normally with no errors, indicating the Heywood case had been resolved. Goodness-of-fit statistics indicated the revised model improved the fit of the model to the data, as displayed in Table 4.20 below (results in SEM #2 column). Overall model fit for this model as assessed with X^2 was unsatisfactory ($X^2 = 19.722$, $df = 11$, $p = .0493$). Model fit was further assessed via CFI and TLI, and CFI exceeded the superior fit threshold of .95. TLI fell just below it but still indicated good model fit (CFI = .969, TLI = .940). The RMSEA value for the tested model indicated good fit, though the 90% confidence interval was wide (RMSEA = 0.059, CI .003-.101). SRMR also indicated good fit (SRMR = .042). An assessment of individual parameter estimates indicated that the cognitive reserve and executive functioning portions of the model were significant, including the relationship between these two latent variables. Neither of the outcome parameters were significant (# of psychological services estimate = -.055, S.E. = .084, $p = .662$; # of infractions estimate = .020, S.E. = .013, $p = .123$), nor was the covariance between education and WCST categories (estimate = .468, S.E. = .272, $p = .085$). A review of R^2 values indicated all were significant. Examination of the modification indices revealed that freely estimating

the covariance between the two WCST variables (# of categories completed and perseverative errors) would significantly improve model fit.

A third analysis of the structural model was run that removed the covariation between the education and WCST categories variables. Fit indices did not change significantly, as displayed below in Table 4.20 (results in SEM #3 column). Individual parameter estimates and R^2 values were all significant except for the estimates for the two outcome variables (# of psychological services estimate = -.051, S.E. = .080, $p = .524$; # of infractions estimate = .020, S.E. = .012, $p = .111$). Additionally, the standardized parameter estimate for the covariance of education and WCST perseverative errors was greater than one (-3.775). A standardized parameter outside the -1 to 1 range is not necessarily a problem, and it indicates the effect has no upper or lower bound (Hayes, 2009). Examination of the modification indices revealed that estimating the covariance between the two WCST variables (# of categories completed and perseverative errors) was still being recommended. The data were run again including this recommended modification and it resulted in a poorer fitting model, so the modification was removed. The final model with parameters is presented in Figure 4.11 below. Standardized and unstandardized parameter estimates are presented in Tables 4.19 and 4.20 below. Overall, after several model modifications the model was not a good fit to the data.

Table 4.18

Goodness of Fit Statistics for Full Structural Equation Model Analyses		
	SEM #2	SEM #3
Chi-Square Test of Model Fit		
Value	19.72	22.79
Degrees of Freedom	11.00	12.00
P-value	0.05	0.03
Chi-Square Test of Model Fit for the Baseline Model		
Value	300.05	300.05
Degrees of Freedom	21.00	21.00
P-value	0.00	0.00
CFI/TLI		
CFI	0.97	0.96
TLI	0.94	0.93
Root Mean Square Error of Approximation (RMSEA)		
Estimate	0.06	0.06
90% Confidence Interval	0 - .10	.02 - .10
Probability RMSEA \leq .05	0.32	0.26
Standardized Root Mean Square Residual (SRMR)		
Value	0.04	0.05

Note: SEM #2 - Full model run after WCST Psv Errors set at .3;
SEM #4 - final version of full structural equation model

Figure 4.11 Standardized Results for the Full Structural Model

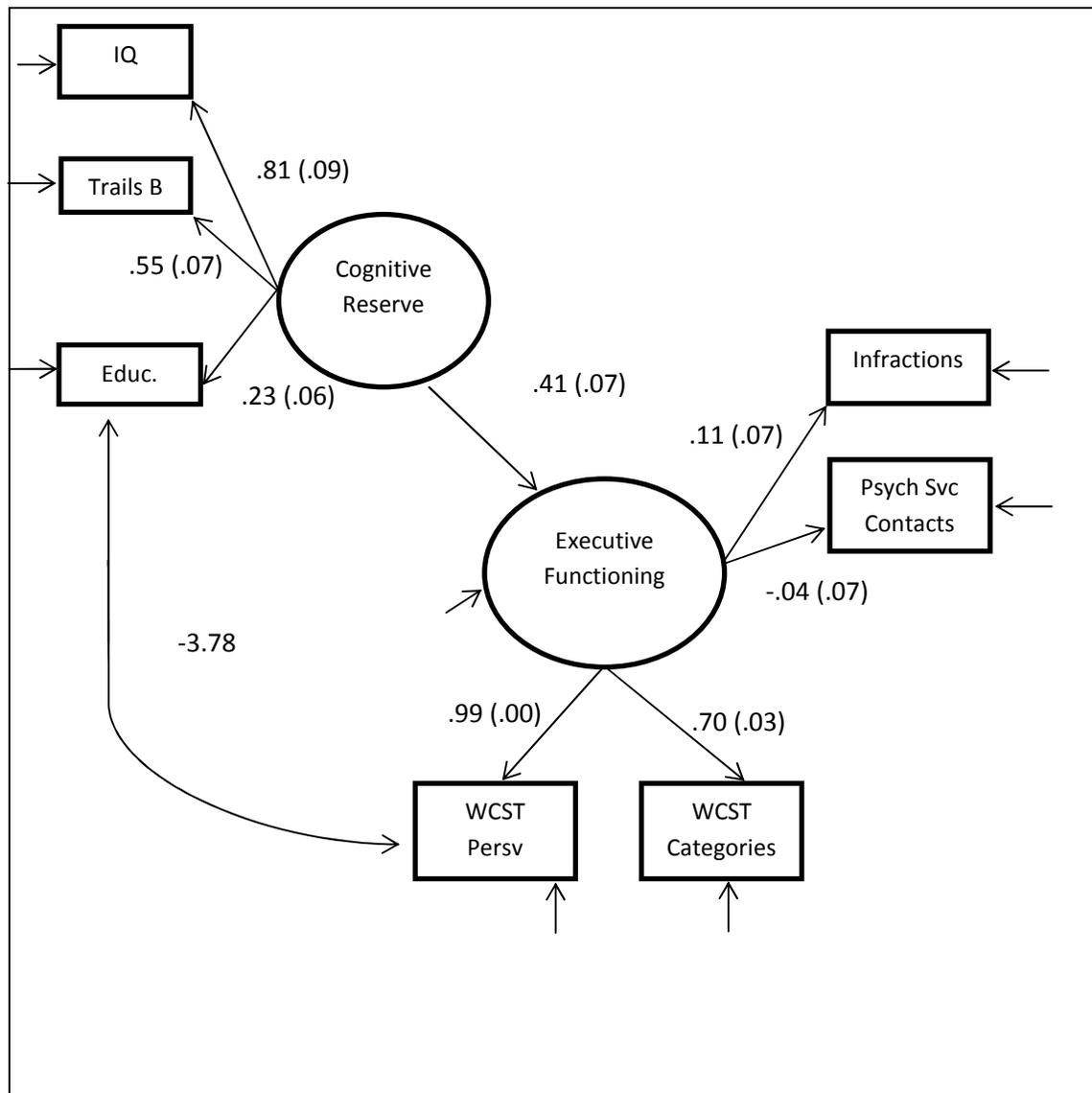


Table 4.19 Standardized and Unstandardized Coefficients for the Measurement Model

Observed Variable	Latent Construct	Unstandardized		Standardized		
		<i>B</i>	<i>SE</i>	β	<i>SE</i>	<i>p</i>
IQ	Cognitive Reserve	1.00		0.81	0.09	0.000
Education	Cognitive Reserve	0.62	0.19	0.23	0.06	0.000
Trails B	Cognitive Reserve	0.61	0.13	0.55	0.07	0.000
Perseverative Errors	Executive Functioning	1.00		1.00	0.00	0.000
Categories Complete	Executive Functioning	0.12	0.01	0.70	0.03	0.000

Table 4.20 Standardized and Unstandardized Parameter Estimates for the Structural Model

Path/Effect	Unstandardized		Standardized		
	<i>B</i>	<i>SE</i>	β	<i>SE</i>	<i>p</i>
Cog Reserve -> Exec Func	3.53	0.92	0.41	0.07	0.000
Exec Func -> # of Psych Sv	-0.05	0.08	-0.04	0.07	0.509
Exec Func -> # of Beh Inf	0.02	0.01	0.11	0.07	0.098

CHAPTER FIVE DISCUSSION

Traumatic brain injury (TBI) in incarcerated and offender populations has been identified as an area of public health concern, even though only a small amount of research data are available to inform our knowledge of the extent of the problem. The existing research suggests that a history of TBI may be related to later violent behavior, criminal activity, mental health problems, and poorer institutional and community adjustment. The rate of TBI among incarcerated populations is of special concern as it appears to be higher than the rate found in the general population (CDC, n.d.; Diamond et al., 2007). The available research on the topic also suggests that incarcerated individuals with TBI have poorer institutional and community outcomes (Merbitz et al., 1995; Shiroma et al., 2010) and a variety of cognitive impairments including executive dysfunction (Stuss & Gow, 1992; Spikman et al., 2000), memory deficits, attention problems, and processing speed deficits (Hannay et al., 2004). Most of the TBI corrections research has focused on its relationship to violent behavior as a result of community safety and policy concerns (Rosenbaum et al., 1994; Leon-Carrion & Ramos, 2003). However, far less research has examined other cognitive and emotional sequelae of TBI among incarcerated adults, and very little research has looked specifically at neuropsychological functioning (Barnfield & Leathem, 1998b; Slaughter et al., 2003) or at executive functioning and TBI (Marsh & Martinovich, 2006).

Research exploring the rate and implications of TBI in incarcerated samples represents a small but growing body of literature, but it indicates that TBI is an area of concern that should be explored more fully. Most studies have identified rates of TBI in

their samples that are much higher than what is found in the general population, though many methodological issues, such as small samples or limited representativeness of samples, make it difficult to generalize from the existing findings (Diamond et al., 2001). The purpose of the current study was to address one of the gaps in the research by examining TBI, neuropsychological functioning, and specifically the executive functioning, of a sample of adults incarcerated in the Federal Prison System. In the sections that follow, the results of the study will be summarized, interpreted, and examined in light of prior research. Limitations of the study will also be discussed, and clinical implications and recommendations for future research will be explored.

Summary of Results

The current study addressed one research question and three hypotheses. One hypothesis was supported and the other two were rejected based on the results described below.

Research Question 1. What is the level of neurocognitive functioning in the domains of IQ, executive functioning, verbal memory, attention, and motor skills for this sample?

Overall, the sample demonstrated average performance across the majority of cognitive domains including IQ, executive functioning, attention and motor skills. When looking at the range of scores, there was significant variability in individual performance. The neuropsychological test scores obtained by the inmates spanned all the way from the profoundly impaired to the superior performance range. The mean and median IQ scores were in the average range, though the modal score fell in the low average range. Similar performance was obtained on the measures of executive functioning (i.e., WCST perseverative errors, total categories, Trails B) with virtually all measures of central

tendency falling in the average range. The one exception was the mean WCST perseverative errors T score (44.44; note: the higher the T score, the fewer the number of errors) which would be considered below average according to Heaton and colleagues' (2004) standards. It should be noted that this score falls just at the border between below average and average of the Heaton qualitative descriptors and would be considered average by other qualitative standards.

Mean and median values for the two measures of attention (Symbol Digit Modalities Test – SDMT, and Trails A) were in the average range, though the modal scores were low average for both measures. Performance on the Grooved Pegboard Test, a measure of motor function, was also generally average. The one area where the sample demonstrated below average performance was verbal memory. The average scores for both immediate and delayed recall fell in the below average range, as did the median values. Interestingly, the modal score for immediate recall fell in the impaired range. Recognition memory for the sample was in the average range. Overall, performance on neuropsychological testing was generally average with a very wide range of performance across individual participants.

Research Hypothesis 1. Individuals reporting more severe head injuries (moderate, severe) will show greater deficits in executive functioning than those reporting mild head injuries or no head injuries.

The sample was divided into three groups; no reported head injury, one or more mild TBIs reported, and one or more moderate or severe TBI reported. Results indicated there was no significant difference in performance on the three executive functioning

measures across the different levels of TBI injury severity, and research hypothesis one was rejected.

Research Hypothesis 2. Individuals with lower cognitive reserve (i.e., substance abuse history, history of TBI, lower IQ, lower educational attainment) will show greater deficits in executive functioning than those with higher cognitive reserve.

The study results partially supported this hypothesis. The cognitive reserve variables predicted a significant amount of the variance in each of the three executive functioning measures (i.e., Trails B, WCST categories completed, and WCST perseverative errors). However, one of the cognitive reserve variables, IQ, uniquely predicted the majority of the variance when the other variables (i.e., substance abuse history, TBI severity, education) were controlled. When looking at Trails B performance, none of the cognitive reserve variables save for IQ was significantly predictive on its own. Two of the four cognitive reserve variables were significantly predictive of WCST perseverative errors when the other variables were held constant, but one of these relationships was surprising. As expected, IQ was significantly predictive and had a positive relationship with performance on this measure (meaning fewer errors were made). However, education was found to have a significant inverse relationship with the measure, which would indicate lower education was associated with better performance. When looking at the second WCST variable, number of categories completed, IQ and education were the only cognitive reserve variables that were significantly predictive of performance when the other variables were held constant. However, in this case education was positively related to performance, such that higher education was predictive of more categories completed.

When considering the results of all three multiple regressions together as they relate to the hypothesis, the cognitive reserve variables were able to predict scores on the executive functioning measures at a statistically significant level. Further, level of cognitive reserve and executive functioning performance were generally positively correlated, supporting the original hypothesis. In contrast to the hypothesis, level of education was slightly negatively related to perseverative error performance on the WCST, such that as education level decreased the T-score for perseverative errors increased (note: the higher the T score, the fewer the number of errors).

Research Hypothesis 3. Individuals with greater executive functioning deficits will exhibit more behavior problems during the first two years of the current incarceration.

Multiple analyses were conducted to explore this hypothesis including simple correlations and a more in-depth exploration using structural equation modeling (SEM). Results of correlational analyses indicated there were no significant relationships between any of the executive functioning measures and the outcome measures, and these results consequently did not support the hypothesis.

A structural equation model was also conducted to test the following relationships:

1. Cognitive reserve and executive functioning will be correlated, and greater cognitive reserve will be positively related to greater executive functioning.
2. Greater cognitive reserve will be positively related to better institutional behavior (i.e., fewer behavioral infractions and psychological services contacts).
3. Executive functioning will mediate the relationship between cognitive reserve and institutional behavior.

The initial model was a poor fit to the data and several modifications were made to both the measurement and structural models. Despite several attempts at modification, the model was not a good fit to the data. Exploration of individual parameter estimates indicated there was a positive relationship between the latent variables cognitive reserve and executive functioning, though no significant relationship was found between executive functioning and the two institutional behaviors (i.e., behavioral infractions, psychological services contacts).

Interpretation of Results

The results of the present study were consistent with previous research exploring the prevalence of TBI in incarcerated samples. However, differences were found in some areas such as overall cognitive performance and the relationship between injury severity and cognitive functioning. In the following sections, comparisons with prior research will be made and explanations for specific findings will be discussed.

Neuropsychological Functioning

In the current study, overall neuropsychological functioning was found to be in the average range. In terms of IQ, prior research with incarcerated samples has primarily demonstrated low average scores (Hanlon et al., 2010; Fishbein et al., 2009), though one study found average IQ performance in their sample of inmates in a state facility (Bryant et al., 1984). Other research utilizing samples of community dwelling adults with histories of domestic violence have also found average IQ results (Cohen et al., 1999; Marsh & Martinovich, 2006). One potential contributor to differences in IQ estimates across studies is the variety of IQ measures used. The current study used the General Ability Measure for Adults (GAMA), while others used the Wechsler Adult Intelligence

Scale (WAIS; Wechsler, 1955; Bryant et al., 1984), the Wechsler Adult Intelligence Scale – Revised (WAIS-R; Wechsler, 1981; Cohen et al., 1999; Marsh & Martinovich, 2006;), the Wechsler Adult Intelligence Scale – 3rd Edition (WAIS-III; Wechsler, 1997; Hanlon et al., 2010), the Institute of Living Scale (Shipley, 1946; Cohen et al., 1999), or the Multidimensional Aptitude Battery (MAB; Sigma Assessment Systems, 1999; Fishbein et al., 2009).

In terms of other areas of cognitive functioning, the Hanlon et al. (2010) study was the only research found that reported standardized scores for their sample across a variety of cognitive tests. Many other research studies only reported comparative analyses (e.g. TBI versus non-TBI) or raw test scores so a direct comparison with the current study's findings could not be made. The average results found in the current study were better than the generally below average performance found in the Hanlon et al. study, though both studies found a wide range of scores within each test. The Hanlon et al. study looked at neuropsychological test performance in a sample of indigent murder defendants and convicted murderers. Results of their study indicated overall low average performance across several cognitive domains including IQ, immediate and delayed verbal recall, attention, and some executive functioning measures. Results on tests of immediate and delayed verbal memory were consistent, with both studies finding low average performance. Results were also consistent for one particular measure of executive functioning, the Wisconsin Card Sorting Test, with both studies finding average performance. Both studies also used Trails A and B, and while the Hanlon et al. study found low average performance on both measures, the current study found average performance.

There are several noteworthy differences between the sample used by Hanlon and colleagues (2010) and the sample used in the current study, which may help to explain the contrast in findings. In the Hanlon et al. study, the sample was drawn from two state correctional institutions and consisted entirely of violent offenders. In contrast, the current sample included federally incarcerated adults that had primarily (64.9%) committed drug offenses (Diamond et al., 2007). This is consistent with prior research showing that violent offenders demonstrate poorer neuropsychological functioning than non-violent offenders (Bryant et al., 1984; Langevin et al., 1987; Hancock et al., 2010). Additionally, while the two samples had similar mean levels of education (Hanlon et al. sample $M = 10.52$ years of education; current study sample $M = 10.73$ years of education), almost half of the subjects in the Hanlon et al. study had a history of special education and/or learning disability, and 15.6% had a documented history of ADHD. In contrast, less than one percent of the current sample had a documented history of learning disability or ADHD. Taken together, the existing research suggests that the cognitive abilities of incarcerated adults vary widely, they are impacted by prior education and learning deficits, and that these differences can be masked when the subgroups are combined (e.g., violent, nonviolent, federal, and state offenders are aggregated).

Traumatic Brain Injury

The current study found a majority of the sample reported a lifetime history of TBI, which is consistent with previous research (Lewis et al., 1986; Schofield et al., 2006). Additionally, the current sample primarily reported injuries that would be classified in the moderate to severe range. This is consistent with some prior research (Marsh & Martinovich, 2006), though other studies have primarily found histories of

mild TBI (Cohen et al., 1999; Slaughter et al., 2003). In contrast, research in the general population has indicated that the majority of TBIs are mild (Holmes et al., 2005). The current results may indicate that, similar to the elevated overall rate of TBI, a history of moderate or severe TBI may also be overrepresented in incarcerated samples relative to the general population. Overall, the current study adds to the existing literature that suggests rates of TBI are significantly higher among incarcerated individuals.

The current study found no statistically significant relationship between injury severity and executive functioning, however. To the author's knowledge, this is the first study that compared executive functioning across injury severity levels in an incarcerated sample. However, prior research has demonstrated a relationship between a history of any TBI and poorer executive functioning among men with a history of domestic violence (Cohen et al., 1999; Marsh & Martinovich, 2006). In general, the research literature indicates that greater injury severity is associated with greater cognitive deficits, though significant variability in outcomes following injury has also been found (National Center for Injury Prevention and Control, 2003). A number of factors can contribute to this variability, such as the offender's age at the time of injury and how long ago the injury occurred (Lezak et al., 2004). Variables such as these may explain why level of injury severity was not related to executive functioning in the current sample. Additionally, the study is relying on self-report data so the accuracy of reported head injuries was not confirmed. Inaccurate reporting may have led to misclassification of injuries which would make it challenging to identify any relationships that existed between TBI severity level and subsequent executive dysfunction.

Executive Functioning and Cognitive Reserve

To the author's knowledge, the current study is the first to explore the relationship between cognitive reserve and executive functioning in an incarcerated sample. Results showed support for a relationship between cognitive reserve and executive functioning. Of the cognitive reserve indicators (i.e. IQ, level of education, history of TBI, history of substance abuse), IQ was the strongest predictor. Prior research has demonstrated a strong relationship between cognitive reserve and executive functioning in a community-based sample (Siedlecki et al., 2009). The current results are consistent with that research and suggest that the construct may also be valid in incarcerated populations.

Executive Functioning and Institutional Behavior

Results of the current study did not support a relationship between executive functioning and subsequent institutional behavior, and to the author's knowledge this is the first study to explore this relationship specifically. Prior research has demonstrated a relationship between a history of TBI and a greater number of institutional behavior infractions (Merbitz et al., 1995; Shiroma et al., 2010b), though no assessment of executive functioning abilities was included in these studies. Other research has found that offenders with executive dysfunction can benefit from treatment (Mullin & Simpson, 2007), but that these deficits can interfere with engagement in standard correctional treatment programming (Fishbein et al, 2009). Overall, the current sample did not demonstrate impaired performance on measures of executive functioning, and half of the sample did not have any behavioral infractions. It is possible that a clear relationship exists between executive functioning deficits and poor behavior, though there is a ceiling

effect for the impact of executive functioning when dealing with primarily non-impaired samples.

Limitations

A number of the limitations of the current study related to sample and measurement issues. For example, the sample size was likely too small for the complexity of the structural equation model proposed. This resulted in low power and likely impacted the precision of the initial correlations and the stability of the model estimates. Additionally, the data did not have a normal distribution which also impacted analyses. For example, one of the executive functioning measures (i.e., WCST categories completed) had a very narrow range of scores. Another limitation related to the data was that all TBI related information was historical self-report, and while this is the most commonly used method of data collection, the accuracy of the data cannot be assessed. The accuracy of the classification of TBI severity level is consequently unknown. The representativeness of the sample presented another limitation when interpreting the data. The current sample consisted primarily of non-violent offenders incarcerated in the Federal Prison System, whereas much of the existing research used state prison populations and had greater numbers of violent offenders. These differences made it difficult to compare the current results with past findings.

Regarding the neuropsychological assessment battery, there are a number of limitations related to interpreting test results. For example, there are multiple ways to explain what test scores mean and it is not always clear which explanation is correct. Effort can play a role in performance on neuropsychological assessment (Lezak et al., 2004) but the current test battery did not include any formal effort measures. Other

factors, such as the testing environment, can have an impact on performance as well.

Suchy (2009) described how many experimental testing environments provide just enough structure that individuals with mild executive dysfunction are able to overcome their weakness, thereby presenting as higher functioning on testing than they would be in real-world situations.

Additional limitations of using clinical measures for research are that many of these tests have a limited range of scores, a low ceiling, and typically produce nonnormal distributions (Suchy, 2009). As described above, the limited range of scores on the WCST impacted the current analyses. Additionally, while the test battery included many measures that are commonly used in research and clinical practice, the research suggests that many of these tests do not have a high level of specificity. This is especially true for tests meant to capture executive functioning (Pukrop et al., 2003; Strauss et al., 2006; Suchy, 2009). One way to address the issue of specificity is to administer a more complex battery of tests so that cognitive domains can be assessed in multiple ways (Suchy, 2009). However, the current study's use of archival data meant that the test battery could not be changed. The brevity of the test battery and limitations of the measures may have interfered with answering the research questions. For example, the measures that were meant to represent unique cognitive abilities (e.g. executive functioning, attention, IQ) likely tapped into multiple cognitive domains. Similarly, while the currently study and many others use one or two measures to represent executive functioning (i.e. Wisconsin Card Sorting Test and Trails B), the research indicates executive functioning consists of multiple elements not completely captured by any one test (Lezak et al., 2004). It is possible that including additional executive functioning

tests, particularly those that better capture inhibition (e.g. Stroop Color-Word Interference), would have shown a clearer picture of the relationships between executive functioning and the other variables.

A similar limitation existed for the cognitive reserve variable in the current study. Brickman and colleagues (2010) recommend that cognitive reserve be estimated by a summary measure that incorporates multiple experiences and abilities (e.g. educational attainment, occupational attainment, social interactions), rather than the use of one or two proxies (e.g. IQ, level of education). No estimate of occupational attainment or social interactions was available in the dataset for the current study, but perhaps the inclusion of these additional elements would have provided a more accurate representation of the cognitive reserve construct. Additionally, a recent theoretical paper suggested that executive functioning may be appropriately considered one element of cognitive reserve (Satz et al., 2011). One final limitation related to how cognitive reserve was operationalized in the current study. The inclusion of history of TBI as one proxy for cognitive reserve may not have been appropriate in some cases, depending on when the last injury occurred. A TBI can impact a person's level of cognitive reserve in multiple ways through damage at the time of injury and use of cognitive resources during recovery (Bigler, 2007). It is appropriate to include a childhood history of TBI as a proxy for cognitive reserve because of its potential impact on the person's level of cognitive reserve in adulthood. However, TBI acquired in adulthood may be more appropriately classified as a neurological insult that is *affected by* an individual's level of cognitive reserve, rather than defined as part of their cognitive reserve.

Finally, none of the measures used in the current study have normative data for use with incarcerated populations. It is likely that the standardized scores are not an entirely accurate representation of the sample's performance because the normative samples used are demographically different from the current sample (e.g. limited representation of non-white participants, higher levels of education).

Implications and Recommendations

The purpose of the current study was to address a gap in the research by examining neuropsychological functioning, and the relationship between executive functioning and TBI, in a sample of federally incarcerated adults. The results of the current study, along with previous research that examined TBI in corrections samples, suggest a number of implications for social and criminal justice policy as well as institution level corrections policy.

Implications for Social and Criminal Justice Policy

It seems clear that the rates of TBI found in incarcerated populations are much higher than those seen in the general public. However, the absence of a consistent tracking system at the Federal or State level makes it impossible to know the true rate of TBI in our nation's prisons. In the past, Congress has acted to gain a better understanding of the incidence and prevalence of TBI in the general population (National Center for Injury Prevention and Control, 2003), and one recommendation that came from their research was that stakeholders in correctional settings conduct more research and standardize the way data are collected in order to address the TBI problem. It appears that this recommendation is still valid, and the development of a standardized method for collecting TBI data in institutions would provide for consistent data collection. This

would allow for greater generalization of research findings, which is not currently possible due to the inconsistent TBI tracking methods used across studies.

Another societal level concern related to TBI is the impaired executive functioning it is often accompanied by (Leininger et al., 1990; Stuss & Gow, 1992; Spikman et al., 2000; Hannay et al., 2004), and the subsequent behavioral, emotional, and social functioning problems associated with executive dysfunction. For example, executive dysfunction can contribute to behavioral changes like an increased risk for violence and aggression (Filley et al., 2001; Dinn et al., 2009) and to other antisocial behavior (Morgan & Lilienfeld, 2000). If, as the research seems to suggest, a significantly higher rate of TBI exists among the nation's incarcerated, then it would follow that higher rates of executive dysfunction and subsequent behavior changes may also be seen. The current study was the first to explore the relationship between executive functioning and behavioral infractions, and while the results were non-significant, further research in this area is necessary.

It is possible that some of the violent and antisocial behavior seen in incarcerated populations may be secondary to TBI, rather than simply to criminogenic thought processes, and more research looking at the relationship between executive functioning and institutional behavior would shed light on this area. This issue seems particularly salient because existing research has shown greater executive dysfunction among offenders with a history of violent offenses. Clarification of the divergent etiologies for violent and antisocial behavior is recommended, as the different causes would require unique types of rehabilitation. Further changes to policy may be necessary as policies

grounded in the belief that punishment is a deterrent are not likely to deter behaviors related to neuropsychological dysfunction.

The current study and other research describing the rates of TBI among the incarcerated also suggest a social justice issue related to current legal policies. It is widely recognized that incarceration already disproportionately affects minority and disenfranchised populations (Bureau of Justice Statistics (a), 2009). Add to this the high rates of TBI and their potential sequelae that result in further punishment within and outside the institution (e.g. behavioral infractions, additional convictions), and it becomes evident that we may be further marginalizing high needs populations. Being that the vast majority of incarcerated adults eventually return to their communities, addressing issues secondary to TBI while they are incarcerated could improve community reintegration outcomes. Further, changing legal policies in ways that increase identification of neuropsychological deficits would provide for rehabilitation, rather than simply more punishment, and could increase the success of these transitions back into the community.

Implications for Corrections Policy

While the current study did not find a significant relationship between executive functioning and institutional behavior within a federally incarcerated sample, prior studies have shown it has an impact on treatment engagement and outcomes (Mullen and Simpson, 2007; Fishbein et al., 2009). Institutions may benefit from increasing screening and cognitive testing of individuals who present with risk factors for possible executive dysfunction (e.g., history of violent offenses, prior TBI, neurologic disorders) in order to better classify the inmate population. Further, providing increased training for correctional officers to increase understanding of the effects of cognitive deficits, and

how to work with individuals who may be impaired as a result (Kaufman, 2001), could improve institutional behavior and decrease the number of infractions obtained by this population. Others have suggested the need for training of correctional staff regarding TBI and its sequelae, as well as developing consultative relationships between mental health and corrections staff (McClearen & Magaletta, 2011).

Treatment implications

The current study and prior research also present several treatment implications for corrections programming. A large body of literature has shown support for cognitive rehabilitation following TBI and other neurologic insults in non-incarcerated populations (Cicerone et al., 2000; Cicerone et al., 2005), including effective interventions for reducing aggressive behavior (Alderman, Davies, Jones, & McDonnell, 1999). Andrews, Bonta and Hoge (1990) made the case for inmate classification in order to provide effective rehabilitation, and it would seem that knowledge of an offender's history of TBI and any neuropsychological dysfunction would be important aspects of classification. This information would also alert treatment providers to incorporate cognitive rehabilitation when necessary. Cognitive-behavioral skills programs have been found to be effective with short-term reductions in recidivism (Blud, Travers, Nugent, & Thornton, 2003), and executive dysfunction has been shown to impact performance in standard programs (Mullin & Simpson, 2007). Specifically, Mullen and Simpson (2007) found that those with poorer executive abilities in certain areas had the greatest benefit from the course.

In contrast, Fishbein and colleagues (2009) found that offenders with certain executive deficits were less likely to succeed in standard treatment programming. Both

the Fishbein et al. and Mullin & Simpson (2007) studies further demonstrate the importance of screening and evaluation of inmates' neuropsychological functioning, and executive abilities in particular, prior to involvement in treatment. Additionally, Ross and Hoaken (2010) recommend integrating individualized functional assessment and rehabilitation, along with opportunities for application and transfer of new skills. Taken together, the evidence supports screening and assessment of neuropsychological functioning, individualized treatment, and the incorporation of programming that specifically targets executive dysfunction.

Future Research

The current study and one other (Marsh & Martinovich, 2006) both found higher rates of moderate and severe TBI than of mild TBI. Future research could explore whether these more severe types of injury, which are more likely to be associated with long-term deficits, are indeed found more often in incarcerated samples. Another important area for future research is executive dysfunction. For example, additional studies could reveal milder executive dysfunction through use of the conceptual level response score on the WCST. The two WCST scores used in the current study (perseverative errors and total categories) capture more severe impairment, while the conceptual level response score is more sensitive to milder deficits. While not detected in the current sample as measured, executive dysfunction has been found to be problematic in other incarcerated samples (Merbitz et al., 1995; Marsh & Martinovich, 2006). As described above, it has also been found to impact treatment outcomes (Mullen & Simpson, 2007; Fishbein et al., 2009). Future research addressing the prevalence of executive dysfunction, its impact on treatment, and effective interventions for addressing

it in incarcerated populations is recommended. In addition, the higher rates of executive dysfunction found among violent offenders, relative to non-violent offenders, is also an important area for further study. Additionally, the current study was the first to explore the relationship between executive functioning and behavioral infractions, and while the results were non-significant, further research in this area is also necessary.

The current study was unique in its use of cognitive reserve theory as a basis for understanding neuropsychological functioning, TBI, and diverse premorbid concerns. Cognitive reserve theory seems well suited to corrections research because it allows the researcher to account for so many of the confounding variables often seen in incarcerated samples (e.g. substance abuse, ADHD, serious mental illness). Future research applying this theory could help to increase our knowledge of individuals with a remote history of TBI and the long-term outcomes of this population. In particular, studies that incorporate the psychosocial aspects of cognitive reserve (e.g. occupational attainment, social interactions) would provide a unique contribution to the literature and may provide new insights into how we can improve the transition from institutions to communities.

Conclusion

In conclusion, the purpose of this study was to extend our understanding of TBI in incarcerated populations by exploring its relationship to executive functioning and institutional behavior. Results added to existing evidence that TBI rates are significantly higher than what is found in the general population. Additionally, the study added to the knowledge base by using cognitive reserve theory to explore the impact of various premorbid factors (i.e. substance abuse, IQ, education, history of TBI) on executive functioning. Results indicated executive functioning was predicted by cognitive reserve

variables. The present study did have several limitations, however. The SEM analyses were impacted by the size of the sample, nonnormality of the data, and the lack of specificity of some of the measures used. This may have contributed to the lack of findings related to a relationship between TBI severity and executive functioning, and to the failure to develop an adequately fitting model. Nonetheless, the current study and prior research indicate that TBI in incarcerated populations may be a significant concern. Its relationship to executive functioning appears to be significant, as it seems to relate to poorer treatment and reintegration outcomes. Research regarding cognitive rehabilitation following TBI in non-incarcerated samples has shown its efficacy (Cicerone et al., 2000; Cicerone et al., 2005), and it has also been found to effectively reduce aggressive behavior following TBI (Alderman et al., 1999). Future research that applies these evidence-based methods with incarcerated populations could be very valuable. In addition, research has demonstrated a relationship between executive dysfunction and violent behavior (Hancock et al., 2010; Hanlon et al., 2010). A need remains for more research regarding interventions for executive dysfunction in incarcerated populations, as effective interventions could help reduce future violent behavior.

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