Fall 2016

The relationship between executive functioning and substance abuse

John M. Tracy

THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONING AND SUBSTANCE ABUSE

by

John M. Tracy, B.A., B.S., M.A.

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

COLLEGE OF EDUCATION
LOUISIANA TECH UNIVERSITY

November 2016

LOUISIANA TECH UNIVERSITY

THE GRADUATE SCHOOL

September 27, 2016

Date

We hereby recommend that the dissertation prepared under our supervision by John M. Tracy

entitled

The Relationship between Executive Functioning and Substance Abuse

be accepted in partial fulfillment of the requirements for the Degree of

Doctor of Philosophy

Supervisor of Dissertation Research

Head of Department

Psychology and Behavioral Sciences

Department

Recommendation concurred in:

Advisory Committee

Approved:

Director of Graduate Studies

Dean of the College

Approved:

Dean of the Graduate School

GS Form 13a
(6/07)

ABSTRACT

Substance use disorders are a widespread issue in society today with approximately 20 million people in the U.S. alone experiencing drug-related problems (Substance Abuse and Mental Health Services Administration, 2012). However, treatment is often ineffectual with approximately 50% of addicted individuals returning to substance use. One factor found to impact individuals' treatment response is their neuropsychological functioning. Drug-abusers frequently exhibit severe executive functioning impairments across a number of domains, and there is evidence that these deficits may be time and substance-dependent. Executive functions are mental processes critical in motivation, planning, and goal-directed behaviors. With extended abstinence, research suggests cognitive improvements will occur for many addicts.

The goal of the present study was to evaluate specific impairments in cognitive abilities and executive functions associated with substance abuse for individuals entering residential treatment and to assess the relationship between self-report executive functioning problems and functioning observed on neuropsychological tests. It was hypothesized that participants would exhibit significant impairments in the areas of working memory, set-shifting, inhibition, planning, verbal fluency, and sustained attention. Further, it was hypothesized that improvements in executive functioning would be observed after approximately 45 days of treatment. Moreover, it was hypothesized that executive functioning measures, both self-report and performance-based, would predict substance-related problems, years of abuse, and problematic personality traits. Finally, better neurocognitive functioning at intake was hypothesized to be related to treatment retention.

This study examined adult participants receiving treatment within a private residential addiction center. Findings generally did not provide support for hypotheses. Results found participants reported significant levels of executive functioning problems but exhibited significantly poorer performance on only one neuropsychological measure (Comprehensive Trail-Making Task) compared to established norms which indicated deficits in set-shifting ability. Further, significant improvements at follow-up testing were observed in only three executive functioning tasks, although fewer executive functioning problems were reported by participants across multiple domains. It may be that more extensive cognitive improvements were not observed given the generally average performance of the sample across the neuropsychological battery administered. Further, the only executive functioning measure found to be a significant predictor of substance-related problems and problematic personality traits was the self-report Barkley Deficits in Executive Functioning Scales. Finally, scores on initial executive functioning measures were not found to be predictive of treatment retention. One possible explanation for these results may be the characteristics of the sample studied as the participants were generally well-educated with likely higher levels of general cognitive functioning compared to similar research.

APPROVAL FOR SCHOLARLY DISSEMINATION

The author grants to the Prescott Memorial Library of Louisiana Tech University the right to reproduce, by appropriate methods, upon request, any or all portions of this Dissertation. It is understood that "proper request" consists of the agreement, on the part of the requesting party, that said reproduction is for his personal use and that subsequent reproduction will not occur without written approval of the author of this Dissertation. Further, any portions of the Dissertation used in books, papers, and other works must be appropriately referenced to this Dissertation.

Finally, the author of this Dissertation reserves the right to publish freely, in the literature, at any time, any or all portions of this Dissertation.

Author John M. Ty

Date September 27, 2016

GS Form 14
(5/03)

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Substance abuse is one of the most prevalent psychiatric and social problems within the United States today. Between 2002 and 2011, the estimated annual number of people exhibiting substance abuse or dependence ranged from 20.6 million to 22.7 million. In 2011, approximately 8% of the population aged 12 or older (20.6 million people) experienced a substance use disorder while only 3.8 million people received any type of treatment (Substance Abuse and Mental Health Services Administration, 2012). Unfortunately addiction treatment often is unsuccessful with 40%-60% of addicted individuals relapsing (National Institute on Drug Abuse, 2012). One factor which may be especially integral in individuals' response to treatment is their cognitive functioning. Deficits in executive cognitive functioning have been exhibited by both substance-abusing individuals and former substance abusers who are currently abstinent. The pattern of deficits displayed are likely to be influenced by an individual's primary drug of choice, length of usage, and level of exposure. For example, alcohol-dependent individuals exhibit significant impairments in executive functions and visual-spatial ability. Interestingly, however, fewer problems and less impairment are found in general intelligence, declarative memory, and language skills compared to healthy controls (Crews et al., 2005). Further, specific cognitive impairments in working memory and attentional abilities have been associated with length of abuse in alcohol-dependent patients with increasing duration of dependence relating to more severe cognitive deficits (Loeber et al., 2009). Importantly, there is substantial evidence to suggest that some cognitive abilities and executive functioning (EF) will improve after a period of sobriety regardless of the drugs administered and abused.

Additionally, the influence of cognitive dysfunction in the treatment process has been examined in a limited fashion, and deficits have been found to be associated with reduced retention, client engagement, and motivation for treatment (Blume, Schmaling, & Marlatt, 2005; Katz et al., 2005; Verdejo-García et al., 2012). Further, Blume and Marlatt (2009) concluded that certain impairments, especially in decision-making, problem-solving, and memory, are likely to prevent some individuals from productively participating in treatment. Notably, neuropsychological assessments appear to be particularly critical given the fact that counselors have been found to be unable to reliably identify clients with cognitive impairments (Fals-Stewart, 1997).

The goal of the present study was to further evaluate specific cognitive impairments of a sample of substance abusers, as well as investigating longitudinal changes in executive cognitive functions exhibited by a unique population of individuals undergoing residential addiction treatment. In addition, this study examined the relationship between EF and response to substance abuse treatment.

Review of the Literature

Executive Functioning

Executive functioning is a complex construct, or metaconstruct, referring to a broad set of mental processes responsible for several goal-directed behaviors, such as planning, self-monitoring, and self-regulating (Goldberg, 2002). These future-oriented processes have been described as "a self-directed set of actions intended to alter a delayed (future) outcome" (Barkley, 2011, p. 11). EF is believed to be critical in higher-order cognitive processes and involves inputs from multiple cognitive domains, such as language, memory, and perception (Duke & Kaszniak, 2000). EF is also believed to be involved in self-evaluations, such as individuals' metamemory judgments (Mäntylä, Rönnlund, & Kliegel, 2010). These supervisory capabilities are generally considered to be produced within the frontal lobes of the human brain and are involved in both neurological activity and behavioral manifestations (Goldberg, 2009).

Lezak (1995) differentiates executive functions from cognitive functions, explaining that EF skills address questions of how and whether an individual performs a particular action. In contrast, cognitive functions are related in terms of what or how much of some specific ability one possesses or exhibits. Importantly, an individual could remain productive and independent in the presence of significant cognitive loss if EF abilities remains intact (Lezak, 1995).

The cognitive and neural processes which are believed to underlie executive functions start to develop in infancy. However, there is some debate over whether the development of EF skills is continuous from early preschool to later preschool years or if these skills differentiate later in the developmental process (Mandell & Ward, 2011). These researchers, in a study utilizing Macaca fascicularis monkeys during infancy and the early juvenile period, found that two independent cognitive skills appear to be especially important in EF development. The modulation of response to novel stimuli and the ability to persist and maintain an appropriate response set while experiencing negative feedback are likely to be critical early skills contributing to other EF abilities (Mandell & Ward, 2011).

Furthermore, Clark, Pritchard, and Woodward (2010) found that measures of EF (inhibition, set shifting, and general executive behavior measures) at age four were predictive of children's math achievement in school two years later. These functions continue to develop throughout childhood and adolescence as related brain areas undergo significant changes. For example, the dorsal lateral prefrontal cortex may be one of the last brain regions to fully develop and it is believed to be associated with impulse control (Giedd, 2004). Researchers have estimated that full maturation of the prefrontal cortex likely does not occur until adults reach their 20s, according to magnetic resonance imaging (MRI) research (Giedd, 2004).

Contemporary research appears to support the notion that there exists no unitary executive function, but instead several diverse functions (Miyake et al., 2000; Stuss & Alexander, 2000). Currently, there is no consensus among researchers on what specific neural and behavioral functions compose the broad term executive functioning (Alvarez & Emory, 2006). However, in spite of there being no complete understanding of these abilities, there are several components which are frequently incorporated into conceptualizations of EF, such as cognitive flexibility, working memory, inhibition, planning, decision-making, and attention.

Models of Executive Functioning

There are various theories and conceptualizations aimed at organizing and describing the "supervisory" cognitive functions that comprise executive functioning (Alvarez & Emory, 2006). The meta-analysis of Alvarez and Emory (2006) describes how factor-analytic studies and empirical and theoretical research have somewhat differed when describing the component processes of EF, resulting in the creation of many interrelated constructs such as cognitive flexibility, problem-solving, response maintenance, working memory, inhibition and switching, and sustained attention. In addition, Hofmann, Schmeichel, and Baddeley (2012) describe the basic elements of EF as subserving the overall process of self-regulation.

One of the original models of EF was proposed by Baddeley (1996) who postulated a model of working memory which includes three components: visuospatial sketchpad, phonological loop, and central executive. Visual and spatial information is organized by the visuospatial sketchpad while phonological information is controlled by the phonological loop. The central executive is formulated and depicted as the central control structure through which other cognitive processes and behaviors are regulated and controlled.

Another model was proposed by Lezak (1995) who states that EF is made up of four main components: volition, planning, purposive action, and effective performance. Volition is defined as the ability to consider one's future needs and having sufficient motivation to formulate an intention to accomplish goals. Planning involves considering available options and breaking down goals into progressive steps. Purposive action involves programming activities in order to control behaviors, especially those that are nonroutine. Finally, effective performance depends on how well one monitors and regulates ongoing behaviors (Lezak, 1995).

Additionally, Barkley (2001) argues against a purely information-processing conceptualization of executive functions as he applies an evolutionary framework to his model of EF. He defines EF as "self-regulation across time for the attainment of future goals" (Barkley, 2011, p. 79). He argues that these functions are forms of behavior-to-the-self that evolved to be private responses as a means of self-regulation. The proposed functions are "private, covert forms of behavior that at one time in early child development (and in human evolution) were entirely publicly observable" (Barkley, 2001, p. 7). This biological adaptation was necessary because of interpersonal competition within group-living species, and these functions shift the behavioral control from the immediate social context to self-regulation which utilizes internal representations concerning one's possible social future. Furthermore, executive functions evolved in order to solve certain adaptive problems, such as social exchange and vicarious learning (Barkley, 2001).

Barkley (2001) explains that response inhibition is the initial function which allows for the four other processes to occur. Nonverbal working memory involves sensory-motor actions and has both retrospective and prospective elements. Private mental representations are produced by this process. This function is sensing to the self, both covert seeing and hearing. Verbal working memory involves the internalization of speech as the related cortical areas are activated without the physical manifestation of speech. This function is known as covert self-directed speech. Covert self-directed emotion involves the self-regulation of affect, motivation, and arousal through the manipulation of the first two functions. Barkley (2001) claims that this function is the foundation of intrinsic motivation. Finally, covert self-directed play, reconstitution, is the process of generating novel goal-oriented actions through the analysis and synthesis of old behavioral units into effective adaptations. This function is analogous to flexibility or fluency (Barkley, 2001).

Recent conceptualizations focus on a three-factor model with the following commonly described aspects of EF; set-shifting, monitoring or updating of working memory, and response inhibition (Diamond, 2013; Miyake et al., 2000). Additionally, Verdejo-García and Pérez-García (2007), based on principal component analysis, argue that there is a fourth independent component of EF beyond these three, decision-making, which is defined as the ability to choose the most adaptive course from a set of possible behaviors. Attention has also been directed to the skills of planning and problem-solving which are believed to be critical elements of EF (Barkley, 2011).

Set-Shifting. Using a latent variable approach, Miyake et al. (2000) examined the underlying differences between the set-shifting, updating of working memory, and inhibition constructs. Set-shifting (also known as cognitive flexibility) is described as the ability to shift between mental sets. This involves switching attention and disengaging from one task in order to engage in a more relevant task set. Additionally, another explanation of this construct is the ability to perform a task despite the effects of proactive interference (Miyake et al., 2000).

Anatomically, Wilmsmeier et al. (2010), using functional magnetic resonance imaging (fMRI), found activation in the bilateral dorsolateral prefrontal cortex (Brodmann's area 46) to be associated with behaviors performed during set-shifting tasks. There is also evidence that the neural activation associated with shifting amongst mental sets is different for individuals with certain psychiatric disorders, such as schizophrenia (Wilmsmeier et al., 2010). Further, Diamond (2013) explained that set-shifting develops later in individuals and builds upon working memory and response inhibition in problem-solving.

Goldberg (2009) refers to this construct as cognitive flexibility through which both stability and plasticity are exhibited. Cognitive plasticity refers to the ability to shift cognitive sets in response to environmental stimuli while cognitive stability refers to one's ability to use internal representations to guide behavior. Goldberg (2009) reports that damage to the frontal lobe can lead to two types of deficits in behavior within these domains, perseverance and field-dependent behavior. Perseverance is a lack of plasticity as one cannot fully switch between mental tasks. Field-dependent behavior refers to the inability to sufficiently stay on task and complete an objective. Goldberg (2009) also describes the term "dynamic bystability" as the ability to both effectively attend to stimuli and successfully shift to new tasks when necessary, without interference from previous sets.

Monitoring or Updating of Working Memory. Updating of working memory representations, also known as monitoring, is believed to be another critical executive function. This function involves several important cognitive skills including monitoring and coding information being held in working memory, while simultaneously manipulating this information in beneficial ways in order to aid in problem-solving needs (Miyake et al., 2000). Other skills are considered to be associated with the function of working memory, such as fluency and reasoning ability which have been found to contribute to the updating component (Verdejo-García & Pérez-García, 2007). Updating of working memory has also been found to be related to an individual's level of effortful control (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013). Working memory tasks are often utilized to measure this ability which has been associated with the dorsolateral portion of the prefrontal cortex (Miyake et al., 2000).

Response Inhibition. An additional major executive function frequently proposed is response inhibition (or inhibitory control). This ability involves the inhibition of prepotent responses. This is the active and intentional suppression of automatic or dominant responses to stimuli. According to Barkley (2001), the term response inhibition has also been used to refer to two other distinct processes. It has also been used to describe the cognitive processes of sensitivity to error and interference control/resistance to distraction. Sensitivity to error refers to the ability to interrupt an ongoing, ineffective response in order to create delay in the decision to continue this response, while interference control is related to the ability to protect self-directed cognitive responses and goal-directed behaviors from extraneous stimuli (Barkley, 2001).

This function is often measured using the Stroop Color-Word Test (Miyake et al., 2000). Further, two of the most commonly used types of tasks for measuring response inhibition are the go/no-go paradigm and the stop-signal task (Criaud & Boulinguez, 2013). Several brain regions are activated during a go/no-go task administration (Swick, Ashley, & Turken, 2011), including multiple areas of the lateral frontal cortex such as the "superior, middle and inferior frontal gyri), the insula, the dorsal medial frontal cortex (including the supplementary and pre-supplementary motor areas), the anterior cingulate cortex, the inferior parietal cortex, the precuneus, as well as the striatum" (Criaud & Boulinguez, 2013, pp.12). However, these researchers go on to explain that not all of these brain areas are directly related to the neural inhibition processes. In their review of fMRI studies, Criaud and Boulinguez (2013) conclude that a portion of the neural activity observed during go/no-go tasks may be related to other executive functions, such as the engagement of working memory resources.

Planning Ability and Problem-Solving. The neurocognitive processes of planning and problem-solving have also been characterized as elements of executive functioning by some researchers (Barkley, 2011), while others have conceptualized these abilities as higher-order skills directly related to executive functions. Planning ability involves the capacity to map out the strategies needed to attain an identified goal and subsequently generate the cross-temporal behavioral structures necessary. Problem-solving ability involves both the construction of an initial plan for goal-directed behaviors as well as the generation of possible alternative options should goal-directed actions be found to be unsuccessful.

Planning and problem-solving have been found to be associated with, and influenced by, several other cognitive processes, including the three primary executive functions (set-shifting, working memory, and response inhibition). For example, fluid reasoning, which involves abstract reasoning, likely has a strong effect on problem-solving skills (Unterrainer et al., 2004). Further, problem-solving is believed to involve the utilization of the working memory function (Barkley, 2011) with the influence of the updating ability increasing as the difficulty of a problem-solving task increases (Miyake et al., 2000). In addition, research suggests that planning time may influence problem-solving ability. Increased preplanning time has been found to be related to scores on problem-solving tasks (Unterrainer et al., 2004). There is also evidence that supports a significant positive relationship between response inhibition and problem-solving (Zook, Davalos, DeLosh, & Davis, 2004). Finally, there appears to be mixed findings in regards to the relation between set-shifting and problem-solving, with Zook et al. (2004) finding no association between these two processes. In contrast, Bugg, Zook, DeLosh, Davalos, and Davis (2006) found a significant positive relationship between shifting and problem-solving abilities, as measured by performance on the Tower of London task.

Sustained Attention. In addition to these executive functions, there are other related cognitive abilities which greatly impact everyday functioning. One of these abilities is sustained attention, also known as vigilant attention, which involves the capacity to maintain attention to specific stimuli, especially in monotonous and uninteresting situations. Evidence suggests that in intellectually unchallenging activities it is often more difficult for individuals to maintain continuous attention as compared to more interesting, variable, and cognitively demanding tasks (Langner & Eickhoff, 2013). Sarter, Givens, and Bruno (2001) explain that sustained attention is a fundamental aspect of attention which indicates one's ability to detect infrequent stimuli over an extended period of time and is associated with activity within the frontal and parietal cortices. In their meta-analysis, Langner and Eickhoff (2013) report that multiple neural regions are associated with sustained attention, including areas of the prefrontal cortex, parietal lobe, and subcortical structures. Further, Yu (2011) proposes a relationship between the process of sustained attention and the function of the neuromodulator acetylcholine. An individual's level of sustained attention is often measured by vigilance tasks. Moreover, sustained attention has been theorized to be one of four types of attention, including shifting attention, divided attention, and focused attention (Lezak, Howieson, & Loring, 2004).

Another related cognitive process which has garnered extensive research is decision-making. This ability has been argued to be an independent component of EF by some researchers (Verdejo-García & Pérez-García, 2007). One model to explain this ability, developed by Damasio, Tranel, and Damasio (1991), is aimed at describing the interaction between emotion and decision-making. The Somatic Marker Hypothesis (SMH) proposes that the somatic states experienced during learning are pivotal in an individual's ability to appropriately respond to previously perceived stimuli. These markers are bodily states which help one identify the value of possible options and allow for decision-making to be a somewhat automated function. However, some researchers have questioned the accuracy and extensiveness of this hypothesis. Colombetti (2008) claims that the SMH contains at least two independent hypotheses. The SMH-G states are needed in decision-making and implement preferences in particular situations. Further, the SMH-S proposes that these somatic markers are also needed to consider possible long-term consequences of potential options (Colombetti, 2008).

There are several additional executive functions which have been formulated and researched, such as self-motivation, verbal fluency, reward processing, and judgment (Barkley, 2011; Golub, Starks, Kowalczyk, Thompson, & Parsons, 2012; Manning et al., 2008). Importantly, all of the primary EF abilities discussed have been studied in terms of their relationships with substance use and dependence.

Executive Functioning and the Human Brain

Research and assessment of executive functioning has historically focused on relating observed behaviors (performance on tasks) with neural activity and brain structures. For example, performance on the Wisconsin Card Sorting Test is believed to be related to activity in the lateral prefrontal and parietal cortices. Additionally, thicker cortex in these identified areas is associated with scores on this measurement tool (Burzynska et al., 2012). Further, several EF tasks have been specifically designed to identify particular types of brain damage, such as the Iowa Gambling Task (IGT) which was originally designed to be a measure of decision-making in order to identify individuals with ventromedial prefrontal cortex damage (Bechara, Damasio, Damasio, & Anderson, 1994).

Overall, many researchers have postulated that executive functions of the human brain are located in the prefrontal cortex of the frontal lobe which is interconnected to all major areas of the brain (Goldberg, 2009). However, there exists significant debate over the nature of the connection between executive functions and frontal lobe regions, specifically whether particular neural areas correspond with specific observable functions.

Alvarez and Emory (2006) reported that there may not be a one-to-one correspondence between frontal lobe activity and specific executive functions. In their meta-analysis, these researchers found that commonly used neuropsychological measures (Wisconsin Card Sorting Test, Stroop Color-Word Interference Test, and Phonemic Verbal Fluency) did not exhibit specificity in measuring frontal lobe functioning. Further, Stuss and Alexander (2000) explain that one major problem in research in EF is the fact that there is inconsistence in the use of both anatomical and psychological definitions. Alvarez and Emory (2006) conclude that there should be an emphasis on the measurement of observable behaviors in relation to executive functions.

Despite these concerns about the efforts to connect psychological constructs to anatomical structures, the relationship between specific cognitive functions and particular brain areas is often examined by studying individuals who have suffered frontal lobe damage. For example, deficits in planning ability and problem-solving abilities (as measured by the Tower of London task) have been found to be associated with lesions in the left anterior frontal lobe (Shallice, 1982). Further, specific brain structures have been found to be related to certain cognitive processes, as the anterior cingulate cortex is considered to be critical for the process of selective attention (Alvarez & Emory, 2006).

Additionally, multiple researchers have focused on three main frontal-subcortical circuits (dorsolateral, ventromedial and orbitofrontal) being involved in several cognitive and motivational processes (Alvarez & Emory, 2006). The dorsolateral frontal cortex has been linked to multiple executive functions, such as set-shifting, planning, and working memory (Duke & Kaszniak, 2000). Damage to the orbitofrontal cortex has been found to be related to socially inappropriate behaviors, impulsivity, and disinhibition. The ventromedial circuit is believed to be involved in motivation, and lesions in this area are associated with apathy and social withdrawal (Alvarez & Emory, 2006).

Impairments in Executive Functioning

Impairment in EF can lead to significant and global problems across a wide range of behavioral domains which often can be recognized by both experts and casual observers. Deficits can lead one to be unable to perform satisfactory self-care, as well as being unable to work independently in an effective manner (Lezak, 1995). An individual's ability to exhibit appropriate social behaviors and maintain normal interpersonal relationships also can be greatly diminished by reductions in EF. Some of the behavioral indications of impairment include emotional lability, flattened affect, irritability, rigidity, impulsivity, decreased grooming and cleanliness, and problems shifting attention, as well as a general decline in self-control and self-direction (Lezak, 1995).

EF abilities, and impairments, have also been found to be associated with specific personality characteristics, psychiatric disorders, and behavioral problems, such as aggression, depression, and certain personality disorders, for both adolescents and adults (Dunkin et al., 2000; Holler & Kavanaugh, 2012; Murdock, Oddi, & Bridgett, 2013; Santor, Ingram, & Kusumakar, 2003; Verdejo-García, Lopez-Torrecillas, Gimenez, & Pérez-García, 2004). Interestingly, EF skills have also been found to be related to religiosity and predictive of postconventional moral reasoning abilities (Cottone, Drucker, & Javier, 2007).

Openness to experience and neuroticism have been found to be significantly correlated with measures of EF, as well as intelligence and fluency (Murdock, et al., 2013; Schretlen, van der Hulst, Pearlson, & Gordon, 2010). In a study examining the relationship between the Big Five personality traits and elements of EF, Murdock et al. (2013) found that lower neuroticism was related to increased updating/monitoring abilities, as was higher levels of openness to experience. Openness was further found to be positively associated with measures of cognitive flexibility. Moreover, higher levels of expressed negative affect appear related to lower response inhibition abilities (Bridgett, et al., 2013). Other researchers have found neuroticism to be negatively correlated with fluency and EF (as measured by the Wisconsin Card Sorting Test) while openness was positively related to these abilities. However, these researchers also found that verbal/crystallized intelligence was more strongly associated neuroticism and openness when compared to EF and fluency (Schretlen, et al., 2010).

Individuals with obsessive compulsive personality traits exhibit decreased performance on objective measures of EF, Spatial Working Memory tasks, ID/ED tasks, and the Stockings of Cambridge task, and report significantly more impairment in abilities when compared to a sample of normal controls (García-Villamisar & Dattilo, 2015). Similarly, individuals with borderline personality disorder exhibit significant deficits in cognitive planning, sustained attention, and working memory when compared to controls (Gvirts et al., 2012). Interestingly, self-harming, borderline-disordered individuals exhibit higher scores on non-planning impulsivity measures when compared with those borderline participants who do not engage in self-harming behaviors. However, these groups do not exhibit significant differences in objective measures of executive functions (Claes, Van den Eynde, Guillaume, Vogels, & Audenaert, 2012)

Further, aggression and EF likely share some of the same neural correlates. EF has been found to be a moderator between physical aggression and emotional distress (Sprague, Verona, Kalkhoff, & Kilmer, 2011). Head injury, decreased verbal intelligence, and EF have been found to be related to higher levels of intimate partner aggression in a sample of male perpetrators (Walling, Meehan, Marshall, Holtzworth-Munroe, & Taft, 2012).

Executive functioning-impaired individuals' difficulties in problem-solving are likely to lead to increased levels of aggression (Hancock, Tapscott, & Hoaken, 2010). Specifically, decreased impulse control was related to acts of aggression in one adult sample analyzed (Stanford, Greve, & Gerstle, 1997). Additionally, in an adolescent sample, response inhibition and interference control were found to be negatively related to disruptive behavior disorders. Within the same adolescent sample, planning ability and problem-solving were found to be negatively associated with anxiety disorders (Holler & Kavanaugh, 2012). Further, self-report executive functions have been found to be predictive of intoxicated aggression in a sample of healthy social drinkers (Giancola, Godlaski, & Roth, 2012). Overall, executive functions are believed to be related to one's ability to inhibit expressions of aggression.

Cognitive deficits, such as impairments in EF, are also associated with major depressive disorder. Specifically, many individuals suffering from depression exhibit deficits consistent with dysfunctions within frontal-subcortical regions (Dunkin et al., 2000). In a meta-analysis aggregating 113 studies, Snyder (2013) found significant deficits in shifting, verbal working memory, inhibition, planning, and updating, as well as other executive functions, in individuals experiencing major depressive disorder. Further, individuals experiencing subclinical dysphoria may also be more likely to exhibit impairments on objective neuropsychological measures.

Interestingly, the long-term usage of antidepressant medications may be associated with increased impairment for individuals suffering from depression (Snyder, 2013). Additionally, individuals with major depression who also exhibit prefrontal dysfunction are more likely to have poorer responses to certain antidepressant medications (Dunkin et al., 2000). Beyond neuropsychological measures of EF, self-report scales may be useful in assessing and identifying individuals with depression. Multiple subscales of the self-report Deficits in Executive Functioning Scale have been found to be significant predictors of participants' level of depression (Knouse, Barkley, &

Murphy, 2013). However, these researchers found the objective battery of EF tests administered was only weakly related to depression scores.

Previous research has identified multiple factors as being associated with significant deficits and declines in EF. Some of the main causes of impairment and deterioration in EF abilities include aging, brain injury, and substance use. During the normal aging process, executive cognitive abilities related to the frontal-parietal network decline significantly (Burzynska et al., 2012). Additionally, cortical thickness in specific brain regions of older adults has been found to be predictive of performance on measures of EF (Wisconsin Card Sorting Test; Burzynska et al., 2012).

In addition, individuals who were exposed to alcohol prenatally exhibit significant impairments in EF when compared to controls. Specifically, children with prenatal alcohol exposure have reduced attentional and response inhibition abilities (O'Brien et al., 2013). These researchers found that alcohol-exposed children exhibit reduced neural activity, in the precentral and postcentral gyri, and behavioral deficits in cued no-go response trials of a response inhibition task (O'Brien et al., 2013).

Moreover, an individual's level of EF is often estimated by performance on neurocognitive tests, such as the Trail-Making Task, Wisconsin Card Sorting Test, and the Stroop Color-Word Interference Test. However, Barkley (2011) argues that self-report scales may be more valid measures of problems performing daily tasks and achieving goals when compared to formal tests. Barkley (2011) postulates that there are several important advantages to using a self-report measure compared to using either objective assessments of EF or direct observation of patients. For example, rating scales allow for the measurement of extremely infrequently exhibited problematic behaviors and allow for the vast experience of an individual across a variety of settings to be considered and estimated which cannot be efficiently done using formal neuropsychological testing practices (Barkley, 2011).

Substance Abuse

Substance Abuse and Psychiatric Impairment

The associations between psychosocial problems and impairments in EF have been extensively examined. Relatedly, research has clearly found high levels of comorbidity with several behavioral problems and psychological disorders being frequently connected to substance abuse, and evidence suggests that these associations may influence, and be impacted by, EF and prefrontal cortex processes. For example, personality disorders are four times more likely to be diagnosed in substance abusers compared to healthy controls (Armstrong & Costello, 2002). Likewise, higher levels of neuroticism and impulsivity have been found to be associated with increased substance use (Terracciano, Lockhenhoff, Crum, Bienvenu, & Costa, 2008). And for men, irritability has been found to mediate the relationship between executive functions and alcohol-related aggression in a sample of social drinkers under the age of 35 (Godlaski & Giancola, 2009).

Substance use also has been found to be associated with a number of other psychological disorders, including mood disorders (both depressive and bipolar disorders) and some anxiety disorders (Verdejo-García et al., 2004; Wittchen et al., 2007). Verdejo-García et al. (2004) explain that the high comorbidity involving substance abuse has been conceptualized in two broad ways. The self-medication hypothesis proposes that depression may be a motivation for substance usage (Weiss, Griffin, &

Mirin, 1992) while other researchers suggest that mood disorders develop as a result of neural changes within monoamine projection pathways caused by drug abuse (Verdejo-García et al., 2004).

Further, impulsive personality traits have been found to be associated with EF test performance for a sample of substance-dependent individuals (Dolan, Bechara, & Nathan, 2008). Also, drug-dependent cocaine-abusers often report manic-like symptoms and tend to exhibit a borderline/antisocial personality pattern (Rosselli, Ardila, Lubomski, Murray, & King, 2001). However, these researchers found no relationship between neuropsychological functioning and personality problems (Rosselli et al., 2001). In contrast, other researchers have found that individuals with comorbid antisocial personality disorder perform significantly worse on neuropsychological measures suggesting that the presence of an additional diagnosis (beyond substance dependence) is in some way related to increased impairment (Stevens, Kaplan, & Bauer, 2001). Interestingly, these researchers concluded that comorbid antisocial personality disorder was a better predictor of cognitive impairment compared to the severity of use for a sample of abstinent substance-abusers (Stevens et al., 2001).

Although there exists evidence pertaining to the relationship between problematic personality characteristics and substance abuse, there is no clear understanding of any potential role of EF in this association. It appears that continuing research is needed to further examine how neuropsychological deficits, personality problems, and substance abuse are related.

Substance Abuse and Executive Functioning

Beyond associations with psychiatric disorders, substance use disorders have also been found to be related to other cognitive and behavior problems, especially those involving executive functions. Previous research has examined this relationship between substance abuse and EF in a number of different manners. Some researchers have studied the connection between specific drugs and exhibited patterns of cognitive deficits while others have focused their investigations on determining how intensity of exposure and length of usage influence functioning and impairment. However, some ambiguous or incomplete results have been demonstrated in previous research. This may be due to many studies in this area only examining users of one substance and few simultaneously analyzing more than two substances with the same measures. It is also critical to consider the characteristics of, and differences between, the acute, residual, and long-term effects of particular substances. Additionally, the direction of causation between functioning and substance use has been considered. Overall, there exists clear evidence that substance abuse and dependence is associated with significant neuropsychological impairments across a number of cognitive domains (Verdejo-García et al., 2004).

Importantly, researchers have identified and organized maladaptive behaviors exhibited by substance-dependent individuals which are related to EF (Bechara et al., 2001; Verdejo-García et al., 2004). These problematic behaviors have been divided into three components, the first being an expectation based on reward predictions and attributions of reinforcing properties to the drug. Also, addicts experience a motivational state wherein a compulsive drive is exhibited. The final element of this process is a decision-making component in which the expectations of immediate reward are considered in comparison to possible long-term negative consequences. Substance-dependent individuals exhibit deficits in these specific processes, and researchers have proposed that these behavioral maladaptations represent impairments in EF, especially in decision-making abilities (Verdejo-García et al., 2004).

These maladaptive behaviors are believed to be associated with the orbitofrontal cortex and involve the computation of motivational valences (Bechara et al., 2001; Verdejo-García et al., 2004). Notably, substance abusers share two problematic behavioral markers with patients suffering from orbitofrontal damage, both frequently are unaware, or deny the existence, of the problems they experience and members of both groups frequently disregard long-term consequences when they seek and choose immediate rewards over possible long-term benefits (Bechara et al., 2001).

Although it is generally believed that substance use causes cognitive deficits, Giancola and Tarter (1999) argue that for some individuals executive cognitive dysfunction may precede substance abuse. It has been proposed that cognitive functioning impairments in individuals may be a critical vulnerability factor in the development of substance use disorders and related behaviors. For example, components of EF, such as impulsivity, may mediate the development of drug dependence in rats (Belin, Mar, Dalley, Robbins, & Everitt, 2008). Additionally, Day, Metrik, Spillane, and Kahler (2013) conclude that frequent cannabis users with executive cognitive deficits (lower working memory and higher impulsivity) may be more likely to develop or experience significant marijuana-related problems compared to users without such cognitive problems. Moreover, executive cognitive functioning in late childhood has been found to be predictive of adolescent drug use for individuals classified as high-risk

(Aytaclar, Kirisci, Tarter, & Lu, 1999). Likewise, childhood neurobehavioral disinhibition has been found to be predictive of substance use disorder problems in early adulthood (Tarter et al., 2003) while response inhibition in childhood is related to adolescent drug and alcohol use problems (Nigg et al., 2006).

In addition, poorer planning ability has been found to be associated with increased sharing of drug use equipment. Specifically, impaired performance on the Tower of London task was found to moderate the relationship between the frequency of injection drug usage and the occurrence of sharing of paraphernalia (Severtson, Mitchell. Mancha, & Latimer, 2009). Further, Dolan et al. (2008) found substance-dependent participants exhibited significantly poorer EF, specifically lower scores on a decision-making task (Iowa Gambling Task), when compared to controls. Interestingly, these researchers found that the existence of a family history of substance abuse was related to an increased risk of impairment. Other researchers have argued that poorer EF and decision-making abilities are related to possible problems effectively making decisions in abstinence related to future drug use and greater likelihood of return to usage (Almeida & Monteiro, 2014).

There exists evidence that extensive use of a variety of illicit drugs, including alcohol, opiates, cannabis, and stimulants, can lead to deficits in a number of areas of EF, and the particular deficits, including the severity of impairment, experienced are substance-dependent for many individuals (Verdejo-García, et al., 2004). For example, Ornstein et al. (2000) found distinct patterns of cognitive problems for amphetamine and heroin addicts, which suggests dysfunction in diverse areas of the cortico-striatal circuitry. Overall, substance-dependent individuals consistently experience and exhibit more generalized executive dysfunction when compared to individuals designated as recreational drug users (Verdejo-García & Pérez-García, 2007).

The functioning of individuals who moderately or infrequently use drugs and alcohol, as well as those who binge, has been investigated with mixed results. In one study (Piechatzek et al., 2009), a substance use group was examined which consisted of mild to moderate users of ecstasy, cannabis or alcohol. Limited differences were found between a control group and this substance use group on multiple measures of cognitive functioning, including EF. In contrast to these results, rave-attending polysubstance users were found to exhibit specific EF deficits, such as decreased perseverance and increased impulsivity, when compared to healthy controls (Verdejo-García et al., 2010).

Additionally, binge drinking may be associated with cognitive deficits. In one study, college students who reported engaging in binge drinking behaviors were found to perform significantly worse on measures of EF, specifically lower scores on the Backward Digit Span task and higher levels of perseverative responses, when compared to controls (Parada et al., 2012). Furthermore, these researchers found male binge drinkers exhibited even more severe impairments compared to female binge drinkers on some measurements (Parada et al., 2012).

Gender does appear to impact the level of severity of cognitive impairments caused by substance abuse. Research indicates that males experience more severe neural effects from chronic drug use (Kaufman et al., 2001). For example, drug-using males have been found to exhibit higher levels of cognitive impairment in visual working memory than females (Ersche, Clark, London, Robbins, & Sahakian, 2006).

Specific drugs have been found to be associated with certain patterns of deficits indicating that it may be critical to consider and study substances independently, whenever possible. Alcohol usage is very common among both illicit substance users and other adult groups. Wittchen et al. (2007) found a cumulative incidence rate of alcohol use of over 95% within a sample of young adults. Further, chronic alcohol use is associated with changes in specific brain areas, such as atrophy of the frontal lobes and hypometabolism in the frontal cortex, and leads to cognitive dysfunction (Zinn, Stein, & Swartzwelder, 2004). The review of Oscar-Berman and Marinkovic (2007) concludes that the neocortex, limbic system, and cerebellum are the neural structures most vulnerable to alcohol abuse.

A majority of alcohol-dependent individuals suffer from mild to moderate neurocognitive impairment (Bates, Bowden, & Barry, 2002). In one sample of alcohol abusers evaluated in early abstinence, multiple cognitive deficits were exhibited, including episodic memory and executive function impairments. Specifically, the alcoholic inpatients examined displayed impairments in all executive areas studied, including updating, flexibility, inhibition, organization (verbal fluency), and integration (Pitel et al., 2007). Further, in a sample of polysubstance-users, alcohol abuse was found to be related to poorer decision-making skills, as well as deficits in fluency (Fernández-Serrano, Pérez-García, Schmidt Río-Valle, & Verdejo-García, 2010).

Zinn et al. (2004) also found deficits in early abstinence when alcohol-dependent individuals were compared to a control group. The alcohol-dependent group exhibited significantly lower performances in both abstract reasoning and cognitive flexibility. The pattern of memory problems of alcohol-dependent participants included retrieval issues but not learning or retention difficulties. These researchers concluded that this pattern suggests frontal lobe deficits. Also, members of the alcohol group self-reported experiencing significantly more cognitive impairments when compared to the healthy control group (Zinn et al., 2004).

Opioid abuse and dependence has been shown to be related to problems in a number of cognitive domains, including attention, memory, and executive function (Ornstein et al., 2000; Rapeli et al., 2006). Specifically, Rapeli et al. (2006) examined early abstinence functioning (with assessment occurring between 5 and 15 days after last opioid usage) in a sample of opioid dependent individuals. These researchers found deficits in executive functions (as measured by the Stroop Task and Ruff Figural Fluency Test), fluid intelligence, and complex working memory (Paced Auditory Serial Addition Test) when compared to healthy controls. However, no deficits were found in episodic memory or simple working memory, as measured by the Digit Span task (Rapeli et al., 2006). Sustained attention also appears to be impacted by the abuse of opiates. Researchers have observed significantly poorer performance on a measure of sustained attention for both methadone-maintained subjects and individuals previously dependent on opiates now in protracted abstinence when these groups were compared to healthy controls (Prosser, London, & Galynker, 2009).

Ersche et al. (2006) found that opiate dependent individuals exhibit impairments in visual memory and planning ability (Tower of London). Interestingly, the subjects studied exhibited no dysfunction on an attentional set-shifting task (Three-Dimensional Intra/Extra Dimensional Set Shift). Similarly, Guerra, Sole, Cami, and Tobena (1987) found deficits in working memory, attention, and verbal fluency in individuals currently abusing heroin. Further, Gerra et al. (1998) did not find significant differences between a control sample and abstinent opiate-abusers on two neuropsychological tests. At four months of abstinence there were no differences between groups on the Digit Symbol and Category Test suggesting cognitive improvements occur within the first few months after usage has ceased.

In addition, extensive use of cannabis has also been found to be associated with multiple cognitive deficits. Users exhibit significantly more perseveration, decreased mental flexibility, and lowered ability to sustain attention (Lundqvist, 2005). Adolescent and young adult cannabis users have been found to exhibit retrieval and immediate verbal memory deficits (Takagi et al., 2011). Adolescent cannabis users also produce reduced psychomotor speed, poorer complex attention, and reduced planning and sequencing abilities in comparison to control group performance (Medina et al., 2007). Similarly, an additional study compared long-term adolescent cannabis users with two control groups, one of which consisted of healthy controls while the other was composed of drug users that were not long-term cannabis users. Schwartz, Gruenewald, Klitzner, and Fedio (1989) found significant differences between the two control groups and the cannabis group on two measures of short-term memory (auditory/verbal and visual/spatial) with the cannabis-using group producing poorer scores. Further, when comparing individuals who began cannabis use before the age of 15 and those that started usage after 15 years of age, the EF performance of late-onset users was superior to early-onset cannabis users (Fontes et al., 2011). These findings suggest that earlier usage of cannabis may result in more extensive impairment.

Although there is strong empirical support that substance use causes long-term neuropsychological impairments, clearly many addictive, as well as illicit, drugs have the capacity to provide positive acute effects. For example, stimulants have been found to enhance human performance within a number of areas, such as decreasing fatigue, increasing vigilance and processing speed, and prolonging effort (Koelega, 1993). Further, intermediate doses of cocaine have been found to facilitate performances on measures of inhibitory control (stop-signal task and cue-dependent go-no-go task). However, increased doses do not produce improvements and likely lead to impairing effects (Fillmore, Rush, & Hays, 2006). Critically, cocaine abusers experience impairments in cognitive flexibility, learning, memory, decision-making, response inhibition, and attention (Lundqvist, 2005; Sofuoglu, Waters, Poling, & Carroll, 2011). Interestingly, in one study assessing cocaine and heroin addicts, polysubstance abusers whose drug of choice was cocaine have been found to exhibit significantly more impaired scores on measures of response inhibition and flexibility compared to polysubstance abusers whose reported drug of choice was heroin (Verdejo-García & Pérez-García, 2007).

There also exists clear evidence that the abuse of other drugs of addiction may lead to significant deficits in functioning. For example, in a sample of current methamphetamine users, Simon et al. (2000) found deficits in working memory (updating), response inhibition, and mental flexibility. Also, deficits in planning ability and visual memory have been found in amphetamine abusers (Ersche et al., 2006). Additionally, adolescent and young adult inhalant users exhibit significant impairment in memory retrieval, learning performance, and verbal memory (Takagi et al., 2011).

Length and Severity of Usage. There have been attempts to investigate the influence of severity and length of substance abuse on levels of impairment. For example, in one sample of opiate and amphetamine users, years of usage was found to not be related to level of executive function impairment (Ersche et al., 2006). In contrast, more severe working memory and attentional impairments have been found to be associated with longer durations of alcohol dependence (Loeber et al., 2009). Individuals dependent on alcohol for more than nine years exhibited significantly greater impairment compared to individuals whose length of dependence was not as prolonged. These researchers also found that the ability to shift among mental sets was not associated with length of time of alcohol abuse (Loeber et al., 2009). Moreover, dose peak of substance usage has been found to be negatively related to attention and executive function (Sclafani, Tolou-Shams, Price, & Fein, 2002).

Additionally, a study examining abstinent polysubstance users (with a mean duration of abstinence of five months) observed that poorer updating abilities (as estimated by measures of working memory, fluency, and reasoning) were predicted by greater severity of usage (Verdejo-García & Pérez-García, 2007). Also, severity of opioid dependence has been found to be associated with greater impairment in task-shifting abilities and increased perseverative responses and errors (Lyvers & Yakimoff, 2003). Overall, it is apparent that research related to the association between EF deficits and length and severity of substance use is inconclusive and further investigation is warranted.

Executive Functioning and Improvement during Abstinence

Another associated line of investigation examines the extent to which cognitive abilities and executive functions improve during early and sustained periods of abstinence. There exists evidence that certain cognitive functions may improve with extended abstinence while other abilities may remain dysfunctional and an individual's drug of choice could be influential in the eventual pattern of abilities observed.

Within several weeks of abstinence, functional and structural brain damage has been found to be partially reversible for alcohol-dependent individuals (Crews et al., 2005; Oscar-Berman & Marinkovic, 2007). There is evidence that within approximately four years of abstinence, former alcoholics will likely experience significantly increased perfusion within the left frontal lobes similar to normal levels of blood flow (Gansler et al., 2000). Further, in a sample of long-term abstinent individuals (average years of abstinence 6.7 years), significant neuropsychological deficits were not present when compared to normal controls, as estimated by performance on measures of cognitive flexibility, attention, and auditory working memory. The only impairment observed after extended abstinence was in spatial processing (Fein, Torres, Price, & Sclafani, 2006). Additionally, research suggests that specific cognitive deficits (such as working memory and verbal fluency) will diminish within three to six weeks of cessation of usage for alcoholics (Crews et al., 2005; Mann, Guenther, Stetter, & Ackermann, 1999; Manning et al., 2008; Oscar-Berman & Marinkovic, 2007).

Similarly, Manning et al. (2008) examined alcohol-dependent inpatients within the first week of intake and after detoxification, during the fourth week of treatment. Significant improvements were found for full-scale IQ (as measured by the WASI), working memory (Letter-Number Sequencing), verbal fluency (Verbal Fluency Test), and verbal inhibition (Hayling Sentence Completion). However, mental flexibility and attentional set-shifting (as measured by the Intra/Extra Dimensional Set Shift) and visual planning ability (Stockings of Cambridge Test) did not improve at follow-up (Manning et al., 2008).

In a study of male alcohol-dependent patients, Mann et al. (1999) found significant improvements at five-week re-test on four of the five Halstead Reitan Battery domains that were dysfunctional during the first week of treatment. These results suggest that significant improvements in multiple cognitive abilities can occur within six weeks of addiction treatment for alcoholics. In addition, Zinn et al. (2004) found that nonverbal abstract reasoning was related to length of abstinence with higher performance associated with the number of days of sobriety for abstinent alcoholics.

In comparison, research is conflicted pertaining to how quickly impairments are alleviated for opiate-dependent individuals, although Rapeli et al. (2006) propose that opioid dependent individuals may regain some cognitive abilities, specifically increased working memory performance, after a period of abstinence. Evidence suggests improvements occur within nine months (Gerra et al., 1998; Mintzer, Copersino, & Stitzer, 2005), and global deficits are not apparent at six weeks of abstinence (Rapeli et al., 2006). One study (Gerra et al., 1998) even indicates that significant improvements can come about within one week of detoxification. Additionally, Mintzer et al. (2005) conclude that general cognitive recovery may occur for abstinent opioid abusers. However, these researchers suggest that methadone maintenance may lead to additional impairment for individuals recovering from opioid dependence when using this medical treatment as a means of reducing or eliminating illicit opioid usage. Abstinent opioid abusers (mean abstinence of nine months) exhibited significantly better scores compared to methadone-maintained individuals on the Recognition Memory Test and the Trail-Making Task while there were no differences found on several other measures (Mintzer et al., 2005). Relatedly, Prosser et al. (2009) found that methadone-maintained individuals exhibited poorer sustained attention scores when compared to abstinent opiate-dependent participants. Similarly, King and Best (2011) found a negative relationship between level of methadone dosage and overall intelligence quotient (IQ) in a sample of problem drug users receiving treatment.

In contrast, when examining both current and former users (abstinence over one year) of opiates or amphetamines, there were no differences on visual memory or planning tasks based on length of abstinence (Ersche et al., 2006). These researchers concluded that neurocognitive impairment continues for several years during individuals' abstinence and indicates damage in the frontal cortex. Moreover, in a sample of polysubstance-dependent males, increasing abstinence was not related to improved neurocognitive functioning (Medina, Shear, Schafer, Armstrong, & Dyer, 2004).

A sample of long-term cannabis-abusing adolescents was tested at six weeks of supervised abstinence. This sample exhibited positive, but non-significant, improvements on two measures of short-term memory at six weeks when compared to scores at intake thus supporting the idea that some deficits may remain for an extended period of time after stopping cannabis usage (Schwartz et al., 1989). In a sample of former heroin and cocaine users with a mean average of five months of abstinence, significant impairments in inhibition, decision-making, updating, and shifting were evident. Further, the level of impairment was greater for the cocaine group on measures of shifting and inhibition compared to the heroin-dependent sample (Verdejo-García & Pérez-García, 2007).

Sclafani et al. (2002) examined abstinent individuals previously abusing either crack-cocaine or both crack-cocaine and alcohol. When assessed during abstinence (at both six weeks and six months) the two groups continued to exhibit significant impairments in multiple functions, including inhibition, memory, and verbal fluency. Overall, there appears to be clear evidence that not all cognitive and executive functioning abilities will return to previous levels following a period of sustained abstinence.

Executive Functioning and Substance Abuse Treatment

There exists limited research concerning how problems in various cognitive domains influence one's ability to successfully complete psychosocial treatments. Deficits in EF have been found to be related to multiple treatment-related variables for individuals undergoing substance abuse treatment, including treatment retention, completion, and relapse (Aharonovich et al., 2006; Morrison, 2011; Verdejo-García et al., 2012). In general, findings suggest that impairments caused by substance abuse can negatively affect treatment response. However, there is minimal research specifically examining how increases in neurocognitive functioning observed during an abstinent rehabilitation period are associated with treatment response and outcome.

In a study examining treatment retention of cocaine-dependent participants, Verdejo-García et al. (2012) observed that poorer EF was significantly predictive of fewer days spent in therapeutic communities. Specifically, the best predictor was scores on the Revised-Strategy Application Test, which measures one's ability to multitask and organize sub-goals during the achievement of a long-term goal. Similarly, reduced treatment retention of cocaine-dependent subjects has been found to be correlated with perseverative errors on a measure of problem-solving (Wisconsin Card Sorting Test). However, no other cognitive measures were associated with treatment progression in this study (Turner, LaRowe, Horner, Herron, & Malcolm, 2009). Streeter et al. (2008), using a logistic regression analysis, found that a measure of cognitive control and inhibition, the Stroop Color-Word Interference Test, was able to significantly predict membership within the two examined groups, treatment completers and non-completers.

In another study (Aharonovich et al., 2006), researchers compared individuals who completed substance abuse treatment (defined as 12 or more weeks of cognitive-behavioral therapy) to those who prematurely withdrew on a number of variables. Their results indicated that the individuals who did not fully complete the substance abuse treatment program had significantly poorer cognitive functioning, in the areas of attention, memory, speed, accuracy, spatial ability, and global functioning, when compared to those individuals who were able to successfully complete treatment. Interestingly, there were no differences between these groups on the Wisconsin Card Sorting Test suggesting that certain executive functions may be more influential in the treatment process for substance-dependent individuals than other abilities (Aharonovich et al., 2006).

Moreover, Rinn, Desai, Rosenblatt, and Gastfriend (2002) propose that denial of significant problems related to alcohol usage may sometimes be associated with cognitive dysfunction instead of a manifestation of an ego defense mechanism. These researchers found that the number of denial-related treatment goals utilized by clinicians was significantly correlated with multiple cognitive deficits, including poorer executive functions, verbal memory, and mental slowness (Rinn et al., 2002).

Morrison (2011) examined the relationship between neuropsychological functioning, after 5 to 10 days within an inpatient detoxification unit, and rate of relapse for participants at 3-month follow-up. Specifically, verbal learning (Rey Auditory Verbal Learning Test), working memory (Letter-Number Sequencing Test), and EF performance (Trail-Making Task B) were significantly and negatively correlated to the number of days of drinking alcohol. Further, EF was a significant predictor of days of drinking at three month follow-up with better cognitive functioning related to fewer days of consumption (Morrison, 2011).

Because of the apparent negative effects cognitive deficits have on therapy, some researchers are beginning to examine medical treatments for specific cognitive problems exhibited by substance-dependent individuals. For example, Sofuoglu et al. (2011) administered Galantamine, a medicinal treatment for Alzheimer's dementia, to a sample of chronic cocaine users for ten days. The cocaine users who received the Galantamine exhibited improved scores on a measure of sustained attention (Sofuoglu et al., 2011).

In addition, general functioning of substance abusers may be influenced by their cognitive deficits. For example, deficits in attention have been found to be predictive of employment problems in a sample of substance abusers receiving outpatient treatment (Mackin, Horner, Harvey, & Stevens, 2005). These researchers suggest that neuropsychological testing may be useful in differentiating substance abusers with potential for risk of employment problems during abstinence.

Blume et al. (2005) examined associations between executive cognitive functions and motivation and readiness to change drinking behavior in a sample of alcohol abusers. These researchers found that contemplation to change was related to higher verbal memory scores. Further, better attention-concentration skills were predictive of lower levels of drinking behavior at follow-up measures during abstinence.

It has been proposed that impairments in decision-making, memory, and problem-solving skills are likely to reduce the ability of certain substance-abusing individuals to effectively participate in treatment (Blume & Marlatt, 2009). These researchers argue that executive cognitive functioning should be considered an important factor in treatment planning and implementation as engagement and appropriate participation may be affected and relapse more likely for those with deficits.

Verdejo-García, et al. (2004) explain how cognitive impairments may negatively impact treatment in two important ways as they may increase the likelihood of drug-seeking behaviors and may interfere with an individual's participation in, and understanding of, rehabilitation programs with an educational or cognitive emphasis. Investigating EF of substance abusers in treatment may be especially important since counselors are ineffective at identifying clients with cognitive impairments (Fals-Stewart, 1997).

Another factor to consider is the utilization of self-report measures of executive functioning in assessments as they are likely to be quicker, cheaper, and more easily administered to individuals with potential substance use disorders. The majority of research examining deficits of substance abusers emphasize performance on neuropsychological measures of cognitive and executive functions with minimal research considering the utility of self-report measures in assessing EF problems. However, in a sample of college students, problematic substance users have been found to score significantly different that non-problematic users on self-report measures of EF problems (Brunelle & Flood, 2016). Another found a self-report measure (Behavior Rating Inventory of Executive Functioning) to be more sensitive than a performance-based measure in differentiating a substance abuse group from a control group (Hagen et al., 2016). These findings support the continued research and utility of including these types of assessments in neuropsychological evaluations of substance abusers.

Overall, there exists evidence that within several weeks to years of abstinence certain cognitive abilities, and executive functions, are likely to improve for substance-dependent individuals. Verdejo-García, et al. (2004) claim that neuropsychological functions begin to recover within the first month of abstinence for substance abusers. There is also evidence indicating that EF impairment can have a negative effect on treatment response. However, there appears to be no clear understanding as to how observed deficits and improvements are related to ongoing substance-related problems, personality characteristics, and treatment response, and it is apparent that further research is needed in order to better estimate the type, speed, and extent of improvements in functioning for abstinent substance-abusers.

The Present Study

The primary purpose of the present study was to further examine the relationship between substance abuse and executive cognitive functioning. Specifically, cognitive performance of substance abusers was analyzed and the relationship between self-report measures and neuropsychological test performance was considered. A three-factor model of EF (including set-shifting ability, response inhibition, and working memory) was investigated. Furthermore, changes in functioning were evaluated in participants undergoing residential substance abuse treatment.

Multiple EF constructs, as well as other cognitive abilities, were measured including: planning ability, set-shifting/cognitive flexibility, working memory, inhibition, verbal fluency, sustained attention, and general intelligence. In addition to neuropsychological measures, self-reported cognitive and executive functioning problems and perceived problematic personality traits were assessed, along with level of substance-related problems. Although there exists extensive research investigating the impairments in neurocognitive functioning of substance abusers, there appears to be a need to further elucidate any changes in functioning during early abstinence and potential predictors of treatment response. Further, the sample evaluated in the present study is likely to be markedly different from most research in this area. Previous research at this facility found the average Full Scale IQ among over 150 referral patients to be 110 (Tracy & Young, 2012). With such a unique population likely possessing higher premorbid cognitive functioning compared to similar investigations, fewer cognitive deficits may be identified.

Hypotheses

Hypothesis One. It is hypothesized that self-reported problems related to executive functions (as measured by the BDEFS) will be negatively associated with multiple neuropsychological measures of functioning (LNS, COWA, CTMT, SNST, GDS, and ToL scores).

Hypothesis Two. It is hypothesized that participants will exhibit deficits at intake compared to established norms in multiple EF areas, including planning ability (as measured by ToL scores), set-shifting (CTMT scores), working memory (LNS scores), inhibitory control (SNST scores), and verbal fluency (COWA scores), as well as sustained attention (GDS scores). Further, participants will likely report increased EF problems (BDEFS scores) when compared to normative samples.

Hypothesis Three A. It is hypothesized that participants will make significant improvements in EF after detoxification and increasing abstinence at 45 days. More specifically, it is predicted that significant improvements in working memory (LNS scores), verbal fluency (COWA scores), set-shifting (CTMT scores), inhibition (SNST scores), and self-reported EF problems (BDEFS scores) will be exhibited at follow-up testing (45 days).

Hypothesis Three B. It is also hypothesized that significant changes in planning ability (ToL scores) and sustained attention (as measured by the GDS) are not expected at follow-up.

Hypothesis Four. It is hypothesized that longer duration of substance usage prior to treatment, substance-related behaviors and problems (AUDIT and SIP-D scores), and level of problematic personality traits (BAT-37 scores) will be predicted by more deficits in neurocognitive functioning across measured domains (scores on GDS, LNS, ToL, COWA, SNST, and CTMT) and self-report EF problems (BDEFS) at intake.

Hypothesis Five. It is hypothesized that higher performance-based scores and lower self-report deficits in EF at initial testing will be associated with treatment progression, as measured by retention at follow-up testing point.

Clinicians, including study investigators, have observed patients exhibit increased abilities to maintain attention, track conversations, organize treatment-related work, and participate effectively in treatment as they progress through a residential treatment program. These hypotheses are designed in order to further understand the observed improvements in cognitive functioning that appear to occur early in treatment and consider how changes are related to treatment participation.

CHAPTER TWO

METHOD

Design

The present study utilized a repeated measures design to identify possible changes in cognitive functioning and EF of inpatients undergoing substance abuse treatment. All incoming residential clients were considered for inclusion in this study and all willing clients were included as none met exclusion criteria. In order to estimate necessary sample size, a power analysis for an ANOVA was conducted. Based on the procedure of Manning et al. (2008), to detect a moderate effect size with approximately 80% power, a sample size of 30 participants is required (Friendly, 2012). Approximately 40 substance-abusing participants were included for the full study. Further, the institutional review boards of the university and the participating addiction treatment facility approved the materials and procedures of this study.

Participants

Participants were males (N = 20) and females (N = 20) between the ages of 19 and 60 years old who were recruited from a private residential addiction treatment facility within the southeastern United States, and participation in this study was completely voluntary. Participants were voluntarily seeking treatment for a substance use disorder (as identified by meeting DSM-IV criteria) and multiple individuals were compelled by a licensing board to undergo treatment. Two major exclusion criteria were active psychosis, as observed by facility personnel or reported by the potential participant, and an initial treatment plan consisting of less than 60 days of residential treatment. Approximately 40% of the patients at this facility are professionals referred by their supervisory board for evaluation/treatment and 25% of the study sample reported seeking treatment in order to maintain current job status. A proportion of recruited participants did not remain at the facility for the complete residential treatment program, or a sufficient number of days to be re-assessed as part of this project. These participants ceased treatment prematurely and were only evaluated at intake and data for these individuals were included and analyzed where appropriate. Of the overall sample, 21 participants were re-administered the measures of neurocognitive functioning (BDEFS, SNST, CTMT, ToL, LNS, COWA, and GDS) and the measure of disordered personality characteristics (BAT-37) with the mean number of days between testing being 44.7 (*SD* = 4.17).

Treatment Facility

The addiction treatment center where this study was conducted is based on a 12-Step, abstinence-based model. Patients progress through four phases of treatment by achieving specific treatment objectives, such as completing a series of standard treatment assignments. It is a residential facility primarily providing 90 days of treatment, although a minority of patients have a treatment recommendation of only 60 days. Patients receive daily psychoeducation concerning substance use and other psychiatric disorders. They participate in at least nine group therapy sessions per week with their specific group and primary counselor, as well as multiple Alcoholics Anonymous meetings weekly. They are also provided with complete medical care, through which detoxification is monitored, from physicians and additional medical personnel.

Instruments

Demographic Questionnaire. A demographic questionnaire was used to collect information on general characteristics of the participants, such as age, sex, race/ethnicity, profession, and educational history, as well as other personal information. Other items asked participants to indicate the primary reason for their admission into treatment. Additional items assessed length of substance usage, specific substances used, drug of choice/major problem drug, and days since last usage.

Alcohol Use Disorders Identification Test (AUDIT). The AUDIT (Babor, De la Fuente, Saunders, & Grant, 1989) was designed as a screening instrument to identify individuals with possible alcohol use disorders. The self-report version of the AUDIT contains 10 questions primarily assessing frequency of alcohol-related behavior and problems within the last year, such as "How often do you have six or more drinks on one occasion?" A majority of these items are answered on a scale ranging from 0 (*never*) to 4 (*daily or almost daily*). Higher scores indicate greater likelihood of alcohol dependence. The AUDIT also provides cut-off scores which classify drinkers into one of four levels indicating level of hazardous drinking and need for intervention. The AUDIT has exhibited favorably sensitivity and acceptable specificity across multiple cultures based on ICD-10 alcohol use disorders. Concurrent validity is indicated by AUDIT scores exhibiting strong correlations with other alcohol screeners. Further, the AUDIT exhibits good test-retest reliability (r =.86) and high internal consistency (Babor, Higgins-Biddle, Saunders, & Monteiro, 2001). Although the AUDIT is often incorporated into a diagnostic interview, it has been found to be effective in identifying individuals with possible alcohol problems as a self-report scale (Babor et al., 2001).

In the present study, the self-report form of the AUDIT was utilized as a measure of level of alcohol-related behaviors and problems. Participants were not classified into levels, instead the variable of interest was total aggregate score with higher scores associated with more severe alcohol-related problems.

Short Index of Problems-Drugs (SIP-D). The SIP-D (Alterman, Cacciola, Ivey, Habing, & Lynch, 2009) is a 15-item scale based on the Drinker Inventory of Consequences (DrInC; Miller, Tonigan, & Longabaugh, 1995). It was developed to measure an individual's negative consequences associated with drug use within the past three months. The SIP-D utilizes items from five domains; physical, social, intrapersonal, impulse control, and interpersonal. Items are answered using a 4-point scale from 0 (*never*) to 4 (*daily or almost daily*). Alterman et al. (2009) found the SIP-D to exhibit good internal consistency (Cronbach's $\alpha = .97$), as well as support for the instrument's concurrent validity. In the present study, the SIP-D was used as a measure of adverse consequences related to drug use. The variable of interest was the total score with higher scores indicating more drug-related problems.

Barkley Deficits in Executive Functioning Scale-Long Form (BDEFS-LF). The BDEFS (Barkley, 2011) was originally developed as a self-report measure assessing EF in adults with Attention Deficit/Hyperactivity Disorder. It was adapted to measure EF within daily life activities of adults across five identified factors of EF. Each factor is measured by a subscale of the BDEFS which contains 89 total items and asks participants to rate items on a scale ranging from 1 (*never or rarely*) to 4 (*very often*).

Additionally, the BDEFS-LF has been found to exhibit satisfactory internal consistency, with all five subscales having Cronbach's alpha of over .91, for a general population normative sample. Further, the test-retest reliabilities at 2-3 weeks were found to range from .62 to .90 for the five subscales and the Total EF Summary Score. Discriminant validity for the BDEFS has been supported by its ability to distinguish clinically-disordered patients, especially adults with ADHD, from general population adults (Barkley, 2011).

The BDEFS-LF was utilized as a self-report measure of EF. It produces scores on five subscales of functioning; Self-Organization/Problem-Solving (items relate to ability to organize thoughts and actions and create solutions to problems), Self-Management to Time (relates to planning and preparing for goal-directed behavior), Self-Restraint/Inhibition (relates to impulsive behavior without considering consequences and inability to take other perspectives), Self-Regulation of Emotion (involves impulsive emotional reactions and ability to calm oneself), and Self-Motivation (involves level of effort in work and getting bored easily). The BDEFS-LF also provides an EF Summary score, EF Symptom Count, and ADHD Index score which summarizes overall perceived EF capabilities.

Brief Assessment of Traits – 37 (BAT-37). The BAT-37 (Mayer, 2012) is a scale originally developed to measure personality traits considered for DSM-5 personality trait criteria. This measurement tool assesses 37 personality facets by asking participants to rate a cluster of three related statements for each facet on a scale ranging from 0 (*does not describe me at all)* to 3 (*describes me well).* Mayer (2012) described the correlations between this assessment and several related scales, indicating support for its construct validity. For the present study, the self-report BAT-37 was utilized to briefly screen for significant problematic personality characteristics exhibited by participants. Scores of 2 or above on any cluster indicate a moderate to high elevation for that particular problematic personality trait. The variable of interest was total BAT-37 symptom count, with higher scores indicating more severe personality characteristics.

Wechsler Abbreviated Scale of Intelligence (WASI). The WASI (Wechsler, 1999) is a short-form intelligence test designed to take approximately 30 minutes to administer. The WASI was used to estimate participants' levels of cognitive ability. As part of the standard evaluation process of the treatment facility, referred participants are administered this measure of both verbal and nonverbal intelligence. The four subtests that comprise the WASI are Vocabulary, Similarities, Matrix Reasoning, and Block Design. The Vocabulary subtest measures language development, verbal learning ability, and word knowledge and asks test-takers to define presented words while the Similarities subtest assesses subjects' ability to explain the similarity between two words or concepts. It primarily measures logical abstract thinking, categorical thinking, and crystallized knowledge. The Matrix Reasoning subtest measures one's ability to identify patterns and complete sets of designs, as well as logic reasoning and abstract reasoning. In the Block Design subtest, participants are asked to replicate presented designs using blocks. It is a measure of spatial visualization and nonverbal concept formation. A full scale intelligence quotient (FSIQ) can be calculated using these four subtests. Additionally, a verbal intelligence quotient (VIQ) is estimated from the Vocabulary and Similarities subtests, and a performance intelligence quotient (PIQ) is determined from the Block Design and Matrix Reasoning subtests.

The WASI IQ index scores have been found to have acceptable internal reliability coefficients (.92 to .98). The validity of the WASI is evidenced by the moderate to high correlations (.66, .84, .88, and .92) between same-named subtests of the Wechsler Adult Intelligence Scale - Third Edition (WAIS-III) and the WASI (Wechsler, 1999).

Comprehensive Trail-Making Task (CTMT). The CTMT (Reynolds, 2002) was designed to evaluate brain injuries, specifically frontal lobe damage. In the present study, the CTMT was used as a measure of set-shifting and divided attention. In this series of tasks, participants are first asked to connect numbers in ascending order. Then, examinees are presented with stimuli containing both numbers and letters and must again connect ascending circles in order while alternating between numbers and letters. Mistakes are corrected by the examiner and the total time of completion was the variable of interest. Trail-Making tasks have been found to be sensitive to both dementia and brain damage (Smith et al., 2008). The CTMT has been found to exhibit adequate reliability, with a coefficient of over .90, and discriminant validity (Reynolds, 2002).

Letter-Number Sequencing (LNS). The Letter-Number Sequencing task was used primarily as a measure of working memory (monitoring). In particular, it measures mental control, attention, and concentration. The LNS task is a subtest of the Wechsler Adult Intelligence Scale - Fourth Edition and it exhibits good psychometric properties, with an internal consistency coefficient of .88, test-retest reliability of .76, and factor loading on Working Memory of .69 (Wechsler, 2008). Further, Beglinger et al. (2005) found no significant changes in performance across multiple administrations within a six-week period indicating no significant practice effects for this measure. Participants are verbally presented with a list of unordered items containing both letters and numbers.

Examinees are asked to verbally respond as they place both the letters and numbers in ascending order. The total number of correct trials was the primary variable of interest, as well as the number of items with the longest correctly answered sequence, which provided an estimate of one's working memory capacity.

Controlled Oral Word Association Test (COWA). The COWA (Benton, de Hamsher, & Sivan, 1994) is a measure of verbal fluency designed to determine neurocognitive ability. Specifically, it examines an individual's ability to spontaneously produce words beginning with one of the three provided letters. Letters were chosen based on difficulty and the number of words in the English language beginning with each letter. It has been found to be sensitive to impairment caused by both brain trauma and disease (Ross, Furr, Carter, & Weinberg, 2006). Lower scores have been found to be related to bilateral frontal and temporal lobe lesions, dementia, and Korsakoff's syndrome, as well as other psychiatric disorders (Sumerall & Timmons, 1997).

In the present study, the FAS and CFL versions of the COWA were used in order to attempt to reduce practice effects. In the initial battery, participants were given 60 seconds in each of three trials to generate as many words as they can that begin with the letters F, A, and S. The follow-up battery used the letters C, F, and L. The total number of words produced over the three trials was used as the variable of interest. Further, Ross et al. (2006) concluded that alternative forms of the COWA will likely produce similar scores.

Gordon Diagnostic System (GDS). The Gordon Diagnostic System (GDS; Gordon, 1988) is a measure of sustained attention and impulse inhibition. Previous research indicates that the GDS is a clinically relevant and sensitive tool in the assessment of ADHD (Mayes, Calhoun, & Crowell, 2001). The GDS is composed of two tasks. The Delay task measures one's level of behavioral suppression and impulsivity while the Vigilance task assesses an individual's level of alertness, arousal, and impulsivity. On the Delay task, participants are asked to score as many points as possible by pressing a button and then delaying and pressing again. If a subject presses the button prematurely, then the individual will not earn a point (correct response) and the timer will reset. The amount of time required before a correct response is possible remains set throughout the task. The measure of interest was the ratio between correct responses and total responses. The Vigilance task requires a participant to respond, as numbers are flashed, when a "9" is presented and preceded by a "1." The measures of interest were the number of correct responses and the number of commission errors.

Stroop Neuropsychological Screening Test (SNST). The Stroop (Trenerry, Crosson, DeBoe, & Leber, 1989) is a measure of inhibitory control and response interference. The Stroop was designed to differentiate individuals with organic cerebral dysfunction, especially those with left frontal cerebral involvement, from normal individuals. There have been multiple variations developed, all of which are based on the same basic paradigm (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006). Initially, in the Color task individuals are asked to read a list of color names. These color names are not printed in their matching colors. In the Color-Word Task, participants are then asked to name the ink color of words printed in incongruous ink. Although there are multiple scoring methods used, a common scoring method involves determining the difference in completion time of the two presented trials (MacLeod, 1991).

The Stroop has exhibited a test-retest reliability of .90 and has been found to differentiate approximately 79% of organically-impaired adults from normal adults. The Stroop test has been found to exhibit reasonable validity (MacLeod, 1991). Alvarez and Emory (2006) concluded that Stroop tests are sensitive to damage in specific regions of the frontal lobes, specifically the lateral and superior medial areas. In the present study, the SNST was used to estimate response inhibition and the effects of interference on reaction time, and the variable of interest was score based on the number of correct responses provided within 120 seconds.

Tower of London (ToL). The ToL (Shallice, 1982) was designed to measure executive planning and problem-solving abilities in individuals with frontal lobe damage. In this task, rods of differing heights are presented containing balls of differing colors. Participants are asked to transition from a start state to a goal state within a specified number of moves and by following particular rules, such as only moving one ball at a time. Several cognitive processes have been related to the ToL task, including visuo-spatial working memory, fluid intelligence, and active verbal rehearsal, and it appears to be measuring an independent construct (Unterrainer et al., 2004). Additionally, this test has been found to be sensitive to individuals with left anterior frontal lobe lesions, as these patients make significantly more errors and exhibit longer planning times compared to control group members (Shallice, 1982). Numerous forms of the test have been developed with internal consistency, test-retest, and split-half reliabilities being described as satisfactory and acceptable (Kaller, Unterrainer, & Stahl, 2012; Schnirman, Welsh, & Retzlaff, 1998).

The computerized Sanzen Tower of London test (Sanzen Neuropsychological Assessment Tests, 2012), which is based on the original design of Shallice (1982) and provides age-stratified normative data, was used in the current study as a primary measure of planning ability. The variables measured were total number of excess moves and preplanning time before initial move is performed.

Procedure

Participants were recruited during the intake process of a residential substance abuse treatment facility. Within seven days of arrival, potential participants were approached by the researchers and asked if they would be willing to volunteer to take part in a multi-stage research project for which no compensation was offered. They were explicitly informed that participation in this project would have no impact on their treatment status. After informed consent was provided by potential participants, then an initial questionnaire with the demographic questionnaire, AUDIT, SIP-D, and BDEFS were incorporated into the standard battery of scales and surveys administered to all incoming patients. If the standard battery of measures was completed before participants were recruited, then this initial research questionnaire was administered independently. A screening process was utilized in order to identify potential participants who exhibited active psychotic symptoms or whose initial treatment plan indicated that the residential treatment program would not be fully completed. This screening included consultation with the patient's primary counselor and a review of the patient's record and treatment plan by a member of the treatment staff who is also a part of the research team. Such clients were included in this study.

The BAT-37, WASI, CTMT, and Stroop are given to all evaluation cases at this facility and this existing data was used by the researchers when available and after consent was provided. The study questionnaires were administered before the neurocognitive functioning measures were presented. The LNS and COWA were administered by one of the study researchers, in that order. The participants then completed a brief battery of computerized tests; first the GDS and then the ToL. The neuropsychological scales were administered within seven days of admission and this initial assessment (including the questionnaires and neuropsychological measures) took approximately 70 minutes to complete. All scales (other than the WASI, AUDIT, and SIP-D) were again administered in the same sequence to all available participants approximately 45 days after intake. This assessment took approximately 80 minutes to complete.

Data Analyses

Hypothesis One states that neuropsychological measures (LNS, COWA, SNST, CTMT, ToL, and GDS) will be negatively associated with self-report measure of EF domains (BDEFS EF Summary, Self-Management to Time, Self-Organization/Problem-Solving, Self-Restraint, Self-Motivation, and Self-Regulation of Emotions). In order to examine this hypothesis, bivariate regression analyses were conducted to estimate the level the relationships between self-report EF scores and variables measuring sustained attention, verbal fluency, working memory, planning ability, set-shifting ability, and response inhibition.

Hypothesis Two states that participants will exhibit lower scores on multiple neuropsychological measures compared to established norms for each test. In order to test this hypothesis, a series of one-sample t-tests were performed for the scores on the, CTMT, LNS, SNST, ToL, COWA, and BDEFS and subscales.

Hypothesis Three states study participants will demonstrate significant improvements at follow-up on LNS, COWA, CTMT, SNST, and BDEFS scores. Significant changes are not expected on to the ToL and GDS tasks. To test this hypothesis, a series of dependent samples t-tests were utilized to examine differences between initial and follow-up scores for participants on neuropsychological measures (LNS, COWA, CTMT, SNST, ToL, and GDS) and self-report measure of EF deficits (BDEFS). Investigators initially planned to utilize days of abstinence prior to initial evaluation as a covariate within a series of ANCOVA procedures. However, the number of clean days before testing was not found to be related to performance on any of the administered measures, thus a dependent samples t-tests were conducted.

Hypothesis Four states that cognitive and EF abilities (both measured by performance and self-report methods) will be negatively associated with duration of substance use, substance-related problems, and problematic personality traits. In order to test Hypothesis Four, four multiple regression analyses were conducted to identify significant predictors of years of substance use, substance-related problems (AUDIT and SIP-D scores), and problematic personality traits (BAT-37 scores) among neuropsychological assessments (LNS, COWA, CTMT, SNST, GDS, and ToL) and self-report problems (BDEFS).

Hypothesis Five states that neurocognitive functioning at intake will be related to treatment progression. In order to examine Hypothesis Five, binary logistic regression analysis was performed to identify significant predictors (independent variables) of treatment retention among the measured executive cognitive functions (GDS, CTMT, LNS, SNST, ToL, COWA, and BDEFS). This binary logistic regression analysis included initial testing scores. The dependent variable to be predicted was treatment retention at time of follow-up testing. Lastly, because of the number of statistical analyses being performed in this study, Bonferroni correction procedures were applied to the statistical tests utilized for the five hypotheses investigated in order to control for inflated type 1 error.

CHAPTER THREE

RESULTS

The purpose of this study was to examine executive functioning abilities of individuals participating in residential substance abuse treatment and assess any alterations in functioning during treatment progression. EF and cognitive abilities were assessed using the LNS, COWA, GDS, ToL, Stroop, CTMT, and BDEFS. The following chapter presents the results of the study. Firstly, sample statistics, including means, standard deviations, and correlation coefficients, are presented. Results of a series of one-sample *t*-tests and dependent samples *t*-tests comparing tests scores to norms and initial scores to follow-up scores are discussed. Additionally, multiple regression analyses were conducted in order to consider relationships between EF measures and years of substance usage, level of problems related to substance usage, and problematic personality characteristics. Finally, logistic regression analysis was utilized to order to consider predictors of treatment retention.

Descriptive Statistics

Participants consisted of individuals receiving treatment at a private, residential substance abuse treatment center. The participants consisted of 20 males and 20 females with their ages ranging from 19 to 60 years of age with a mean age of 37.4 (SD = 10.50). The sample was composed of 38 Caucasian Americans (95%) and 2 African-Americans (5%), with 60% of these individuals possessing a college degree and a further 27.5%

having some college experience. The mean number of days reported without substance use before initial testing occurred was 14.92 (*SD* = 9.57) with the range being 1 to 42 days.

In addition, 45% of the sample indicated that primary motivation for treatment concerned being tired of current situation and wanting to make life changes. A further 25% reported seeking treatment in order to maintain their current work status. The most frequently reported drugs of choice for the present study were alcohol (32.5%), opiates/analgesics (30%), and amphetamines (15%), with 5 participants reporting 2 drug types. Complete demographic information of the study sample is presented in Table 1.

Table 1. Descriptive Statistics of Sample

Variable	Frequency	Percentage
Gender		
Males	20	50.0
Females	20	50.0
Ethnicity		
Caucasian	38	95.0
African-American	2	5.0
Drug of Choice		
Alcohol	13	32.5
Opiates/Analgesics	12	30.0
Sed/Hyp/Tranq	4	10.0
Cocaine	4	10.0
Amphetamines	6	15.0
Cannabis	1	2.5
Reason for Treatment		
Tired of Situation	18	45.0
Family Pressure	5	12.5
Legally Ordered	4	10.0
Job-Related	10	25.0
Other	1	2.5

Table 2 displays descriptive statistics of the initial scores on measures of substance use problems (AUDIT and SIP-D), executive cognitive functioning (LNS, COWA, CTMT, SNST, GDS, ToL, WASI and BDEFS), and problematic personality characteristics (BAT-37). The means, standard deviations, minimum scores, and maximum scores of study variables at the initial testing are presented.

Table 2. Descriptive Statistics of Initial Testing

Variable	*N*	Mean	*SD*	Minimum	Maximum
AUDIT	38	12.74	12.35	0	35
SIP-D	38	30.21	10.59	1	45
BAT-37	38	9.97	7.48	0	31
BDEFS-T	38	195.34	61.22	94	344
BDEFS-1	38	48.29	18.13	10	84
BDEFS-2	38	50.32	18.44	26	91
BDEFS-3	38	43.55	14.49	20	76
BDEFS-4	38	22.76	9.53	12	48
BDEFS-5	38	29.63	10.89	14	52
BDEFS-SC	38	30.61	25.92	0	86
LNS	40	9.45	1.93	5	14
COWA	40	40.30	13.35	14	69
SNST	35	99.51	15.22	49	112
CTMT	37	41.35	9.67	17	59
GDS-1	39	0.79	0.13	0.30	1
GDS-2	39	42.85	5.09	15	45
GDS-3	39	2.26	4.09	0	12
ToL-1	37	8.76	8.72	0	46
ToL-2	37	6.88	2.06	3.45	13.53
WASI-1	16	106.75	7.66	92	117
WASI-2	16	108.50	9.416	94	130
WASI-3	16	104.06	7.75	87	114

AUDIT = Alcohol Use Disorders Identification Test; SIP-D = Short Index of Problems-Drugs; BAT-37 = Brief Assessment of Traits – 37; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; BDEFS-1 = BDEFS Self-Management to Time; BDEFS-2 = BDEFS Self-Organization/Problem-Solving; BDEFS-3 = BDEFS Self-Restraint; BDEFS-4 = BDEFS Self-Motivation; BDEFS-5 = Self-Regulation of Emotions; BDEFS-SC = BDEFS Symptom Count; LNS = Letter-Number Sequencing Standard Score; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total CommissionsToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move WASI-1 = Wechsler Abbreviated Scale of Intelligence Full-Scale IQ; WASI-2 = Verbal IQ; WASI-3 = Performance IQ; *N* = number of participants; *SD* = Standard Deviation.

Table 3 consists of results of neuropsychological measures, self-report EF problems, and problematic personality characteristics at follow-up testing. The means, standard deviations, minimum scores, and maximum scores for the measures of sustained attention, verbal fluency, working memory, planning ability, set-shifting ability, response inhibition, self-report EF problems, and problematic personality characteristics are displayed.

Table 3. Descriptive Statistics of Follow-Up Testing

Variable	*N*	Mean	*SD*	Minimum	Maximum
BAT-37	20	7.65	6.21	0	23
BDEFS-T	20	161.60	54.77	95	312
BDEFS-1	20	38.10	15.27	21	75
BDEFS-2	20	44.95	16.55	25	84
BDEFS-3	20	36.00	11.03	22	65
BDEFS-4	20	18.65	8.62	12	43
BDEFS-5	20	23.90	8.10	13	45
BDEFS-SC	20	17.65	22.24	0	80
LNS	21	10.24	2.05	8	16
COWA	21	43.95	10.89	28	61
SNST	21	108.57	6.23	86	112
CTMT	21	49.10	11.30	33	79
GDS-1	21	0.869	0.093	0.53	1
GDS-2	21	43.71	2.05	38	45
GDS-3	21	.62	.74	0	22
ToL-1	18	6.00	3.24	1	12
ToL-2	18	5.29	1.35	3.56	8.97

BAT-37 = Brief Assessment of Traits – 37; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; BDEFS-1 = BDEFS Self-Management to Time; BDEFS-2 = BDEFS Self-Organization/Problem-Solving; BDEFS-3 = BDEFS Self-Restraint; BDEFS-4 = BDEFS Self-Motivation; BDEFS-5 = Self-Regulation of Emotions; BDEFS-SC = BDEFS Symptom Count; LNS = Letter-Number Sequencing Standard Score; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; *N* = number of participants; *SD* = Standard Deviation.

Further, a series of one-way ANOVAs were conducted in order to identify any initial differences between genders on study variables, including measures of EF and problematic personality characteristics. No significant differences between males and females were found for any of the neuropsychological tasks administered, and there was no difference based on gender on the measure of problematic personality characteristics utilized. In addition, across the five subscales, EF symptom count, and summary scores of the BDEFS, only one significant difference was found. On average, female participants reported significantly more problems with self-organization and problem-solving abilities when compared to male subjects, $F(1, 36) = 8.627$, $p = .006$, $d = .95$, with a large effect size.

Table 4. Differences between Genders across Study Variables

Variable	Males Mean (*SD*)	Females Mean (*SD*)	*F*	*p*
AUDIT	15.00 (12.70)	10.47 (11.90)	1.285	.264
SIP-D	29.11 (11.72)	31.32 (9.53)	.407	.528
BAT-37	8.68 (6.92)	11.26 (7.97)	1.134	.294
BDEFS-T	176.79 (49.39)	213.89 (67.36)	3.750	.061
BDEFS-1	46.63 (14.86)	49.95 (21.19)	.312	.580
BDEFS-2	42.32 (11.85)	58.32 (20.58)	8.627	.006**
BDEFS-3	39.74 (13.11)	47.37 (15.13)	2.763	.105
BDEFS-4	21.00 (7.67)	24.53 (11.02)	1.311	.260
BDEFS-5	27.11 (10.98)	32.16 (10.47)	2.107	.155
BDEFS-SC	24.37 (22.26)	36.84 (28.34)	2.276	.140
LNS	9.60 (1.82)	9.30 (2.08)	.236	.630
COWA	42.50 (14.87)	38.10 (11.60)	1.088	.303
SNST	101.28 (16.67)	96.79 (13.53)	.812	.374
CTMT	42.00 (7.47)	40.74 (11.56)	.154	.697
GDS-1	.78 (.10)	.80 (.15)	.310	.581
GDS-2	42.11 (6.67)	43.55 (2.95)	.623	.435
GDS-3	2.79 (4.88)	1.75 (3.21)	.780	.383
ToL-1	8.50 (9.90)	9.06 (7.37)	.037	.849
ToL-2	7.31 (2.21)	6.37 (1.80)	1.955	.171

AUDIT = Alcohol Use Disorders Identification Test; SIP-D = Short Index of Problems-Drugs; BAT-37 = Brief Assessment of Traits – 37; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; BDEFS-1 = BDEFS Self-Management to Time; BDEFS-2 = BDEFS Self-Organization/Problem-Solving; BDEFS-3 = BDEFS Self-Restraint; BDEFS-4 = BDEFS Self-Motivation; BDEFS-5 = Self-Regulation of Emotions; BDEFS-SC = BDEFS Symptom Count; LNS = Letter-Number Sequencing Standard Score; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; $*p < .05$ $**p < .01$.

Correlations between Neuropsychological Variables

Table 5 displays Pearson correlation coefficients between initial scores on the administered neuropsychological tests (LNS, COWA, CTMT, SNST, ToL, GDS, and WASI). Multiple correlations were found to be significant, including the relationship between set-shifting ability (CTMT) and response inhibition (SNST) which was $r(37) = .555$, $p = .000$. In addition, a significant positive correlation, $r(40) = .529$, $p = .000$, was found between measure of working memory (LNS) and verbal fluency (COWA), while a significant, and negative, relationship was found between a measure of planning ability (ToL excessive moves) and sustained attention (GDS Vigilance total correct score), $r(36) = -.666$, $p = .000$. Moreover, the WASI-FSIQ was not found to be significantly associated with any other cognitive measure. In addition, the average time to first move of the ToL was also not significantly related to any other measures administered at initial testing.

Table 5. Correlation Matrix of Neuropsychological Variables

Variable	1	2	3	4	5	6	7	8	9	10
1-LNS										
2-COWA	.529**									
3-CTMT	.269	.251								
4-SNST	.279	.077	.555**							
5-GDS-1	.321*	-.007	.025	.132						
6-GDS-2	.358*	.112	.468**	.654**	.367*					
7-GDS-3	-.366*	-.047	-.485**	-.640**	-.377*	-.950**				
8-ToL-1	-.165	-.040	-.414**	-.519**	-.102	-.666**	.610**			
9-ToL-2	-.110	-.053	-.127	.166	-.023	.154	-.121	-.183		
10-WASI	-.069	.401	.512	.232	-.205	-.126	.059	-.090	.210	

LNS = Letter-Number Sequencing Standard Score; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; WASI = Wechsler Abbreviated Scale of Intelligence Full-Scale IQ; $*p < .05$ $**p < .01$.

Results for Hypotheses

Hypothesis One. Hypothesis One states that self-report measure of EF (BDEFS and subscales) will be related to scores on performance measures of cognitive abilities (LNS, COWA, GDS, SNST, CTMT, and ToL) at initial testing. In order to assess Hypothesis One, Pearson correlations were conducted to examine the relationships between BDEFS scores (subscales and total EF Summary scores) and scores on the LNS, COWA, SNST, CTMT, GDS, and ToL at initial testing. Due to the number of tests being conducted, Bonferroni correction was applied to these series of correlation coefficients with an adjusted p-value of $p = .006$.

Results of the analyses identified no cognitive ability was significantly related to BDEFS scores at intake, after applying a Bonferroni correction. The strongest correlation found, although not significant, was between the GDS Vigilance Task Total Correct score and BDEFS Total EF Summary score $r(37) = -.405, p = .013$ indicating that higher vigilance scores may be related to fewer reported EF deficits. These findings are inconsistent with the hypothesized results. Table 6 presents the Pearson correlation coefficients.

Table 6. Pearson Correlations between BDEFS Total EF Summary Score and Cognitive Functioning Measures at Initial Testing

Cognitive Measures	*N*	*r*	*p*
LNS	38	.056	.738
COWA	38	-.090	.590
SNST	35	-.147	.401
CTMT	35	-.203	.242
GDS-1	37	-.069	.685
GDS-2	37	-.405	.013*
GDS-3	37	.298	.073
ToL-1	35	-.100	.566
ToL-2	35	.012	.944

BDEFS = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; LNS = Letter-Number Sequencing; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London-Excess Moves; ToL-2 = Time to First Move; N = number of participants; R = Pearson correlation value; P = probability; $*p < .05$ $**p < .006$ (Bonferroni-corrected p-value).

Results identified no significant relationships between the BDEFS Self-Management to Time subscale and executive functioning variables, after applying a Bonferroni correction. Again, the strongest nonsignificant correlation was between the

Self-Management to Time subscale and the Vigilance Task Total Correct score, $r(37) = -.390, p = .017$. Table 7 presents the Pearson correlation coefficients.

Table 7. Pearson Correlations between BDEFS Self-Management to Time Subscale and Cognitive Functioning Measures at Initial Testing

Cognitive Measures	*N*	*r*	*p*
LNS	38	.097	.561
COWA	38	-.043	.799
SNST	35	.106	.545
CTMT	35	-.133	.445
GDS-1	37	-.233	.164
GDS-2	37	-.390	.017*
GDS-3	37	.298	.074
ToL-1	35	-.233	.179
ToL-2	35	.119	.494

BDEFS = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; LNS = Letter-Number Sequencing; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London-Excess Moves; ToL-2 = Time to First Move; N = number of participants; R = Pearson correlation value; P = probability; $*p < .05$ $**p < .006$ (Bonferroni-corrected *p*-value).

After applying a Bonferroni correction, no significant relationships were found between the BDEFS Self-Organization/Problem-Solving subscale and any of the neuropsychological measures administered at initial testing. The strongest nonsignificant correlation was between the Vigilance Task Total Correct score and self-report organizational problems, $r(37) = -.259, p = .029$. Table 8 presents the Pearson correlation coefficients.

Table 8. Pearson Correlations between BDEFS Self-Organization/Problem-Solving Subscale and Cognitive Functioning Measures at Initial Testing

Cognitive Measures	*N*	*r*	*p*
LNS	38	.066	.692
COWA	38	-.069	.680
SNST	35	-.181	.299
CTMT	35	-.175	.316
GDS-1	37	-.113	.507
GDS-2	37	-.259	.029*
GDS-3	37	.230	.170
ToL-1	35	.037	.832
ToL-2	35	-.246	.154

BDEFS = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; LNS = Letter-Number Sequencing; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London-Excess Moves; ToL-2 = Time to First Move; N = number of participants; R = Pearson correlation value; P = probability; **p* < .05 **p* < .05 ***p* < .006 (Bonferroni-corrected *p*-value).

Results identified no significant relationships between the BDEFS Self-Restraint subscale and any of the neuropsychological measures administered at initial testing. Table 9 presents the Pearson correlation coefficients.

Table 9. Pearson Correlations between BDEFS Self-Restraint Subscale and Cognitive Functioning Measures at Initial Testing

Cognitive Measures	*N*	*r*	*p*
LNS	38	.047	.777
COWA	38	-.100	.549
SNST	35	-.186	.286
CTMT	35	-.194	.263
GDS-1	37	.103	.543
GDS-2	37	-.257	.124
GDS-3	37	.205	.224
ToL-1	35	-.055	.755
ToL-2	35	.112	.521

BDEFS = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; LNS = Letter-Number Sequencing; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London-Excess Moves; ToL-2 = Time to First Move; N = number of participants; R = Pearson correlation value; P = probability; $^{*}p < .05$ $^{**}p < .006$ (Bonferroni-corrected *p*-value).

The BDEFS Self-Motivation subscale was found to be negatively correlated to one neuropsychological measure, the Vigilance Task Total Correct, $r(37) = -.474$, $p = .003$, after applying a Bonferroni correction. Findings suggest that better vigilance abilities, and reduced impulsivity, are related to fewer problems with self-motivation and level of work effort. Table 10 presents the Pearson correlation coefficients.

Table 10. Pearson Correlations between BDEFS Self-Motivation Subscale and Cognitive Functioning Measures at Initial Testing

Cognitive Measures	*N*	*r*	*p*
LNS	38	.059	.724
COWA	38	-.037	.827
SNST	35	-.161	.357
CTMT	35	-.151	.387
GDS-1	37	-.099	.559
GDS-2	37	-.474	.003*
GDS-3	37	.316	.057
ToL-1	35	-.221	.202
ToL-2	35	.034	.845

BDEFS = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; LNS = Letter-Number Sequencing; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London-Excess Moves; ToL-2 = Time to First Move; N = number of participants; R = Pearson correlation value; P = probability; *$p < .05$ **$p < .006$ (Bonferroni-corrected *p*-value).

Results identified no significant relationships between the BDEFS Self-Regulation of Emotions subscale and the neuropsychological measures administered at initial testing after applying a Bonferroni Correction. Table 11 presents the Pearson correlation coefficients.

Table 11. Pearson Correlations between BDEFS Self-Regulation of Emotions Subscale and Cognitive Functioning Measures at Initial Testing

Cognitive Measures	*N*	*r*	*p*
LNS	38	-.056	.739
COWA	38	-.153	.361
SNST	35	-.206	.236
CTMT	35	-.121	.490
GDS-1	37	.074	.663
GDS-2	37	-.326	.049*
GDS-3	37	.277	.098
ToL-1	35	-.009	.958
ToL-2	35	.074	.671

BDEFS = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; LNS = Letter-Number Sequencing; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London-Excess Moves; ToL-2 = Time to First Move; N = number of participants; R = Pearson correlation value; P = probability; $*p < .05$ $**p < .006$ (Bonferroni-corrected *p*-value).

Hypothesis Two. Hypothesis Two states that participants will exhibit lower scores on multiple neuropsychological measures compared to established norms for each scale. In order to test this hypothesis, a series of one-sample *t*-tests were performed for the initial scores on the CTMT, LNS, SNST, ToL, COWA, and BDEFS, and these analyses had a Bonferroni correction applied resulting in an adjusted *p*-value to test for significance of .004.

The BDEFS was utilized as a self-report measure of multiple executive functions across five subscales, a summary score, and an EF symptom count. Initial EF Summary scores of the BDEFS for the study participants were found to be significantly different from the norm group with participants reporting higher levels of EF deficits (M = 195.34, SD = 61.22) than the normative sample (Barkley, 2011; M = 133.90). This significant difference, $t(37) = 6.187$, $p = .000$, represents a large effect size, $r = .72$. Further, participants reported a significantly higher number of EF symptoms (M = 30.61, *SD* = 25.92) when compared to a norm group (*M* = 7.31), $t(37) = 5.541$, $p = .000$, with a large effect size, $r = .67$.

In addition, study participants, on average, reported more problems with self-organizing skills (*M* = 48.29, *SD* = 18.13) than the normative group (*M* = 35.99) at initial testing. This difference was found to be significant and represents a moderate to large effect size, $t(37) = 4.182$, $p = .000$, $r = .56$. Participants also endorsed significantly more time management problems (*M* = 50.32, *SD* = 18.40) when compared to the norm group (*M* = 34.30), $t(37) = 5.354$, $p = .000$, with a large effect size, $r = .66$. In terms of perceived self-restraint, the normative sample reported fewer problems (*M* = 28.47) than study sample (*M* = 43.55, *SD* = 14.49), and this difference is statistically significant, $t(37) = 6.419$, $p = .000$, and represents a large effect size, $r = .73$.

Moreover, at initial testing, participants endorsed a higher number of problems with emotional regulation (*M* = 22.76, *SD* = 9.53) when compared to the normative sample (*M* = 19.38). This difference was found to be statistically significant with a moderate effect size, $t(37) = 2.188$, $p = .035$, $r = .34$. Finally, a higher level of problems with self-motivation and effort in work was reported by participants (*M* = 29.63, *SD* = 10.89) compared to the normative sample (*M* = 15.37). The observed difference was found to be significant and shows a large effect size, $t(37) = 8.074$, $p = .000$, $r = .80$. These significant differences were consistent with predicted self-report deficits of the substance-abusing sample participants.

Initial scores of the CTMT, a measure of set-shifting and divided attention, were found to be significantly different from the mean of the norm group and this discrepancy supports the stated hypothesis. On average, study participants spent more time (composite t-score $M = 41.35$, $SD = 9.67$) completing the trail-making tasks compared to the norm group (composite t-score $M = 50$, $SD = 10$). This difference was found to be significant, $t(36) = -5.44$, $p = .000$, and represents a large effect size, $r = 0.67$.

The SNST was utilized to examine interference effects, response inhibition, and possible brain damage among study participants. Initial SNST scores of the participants ($M = 98.97$, $SD = 15.10$) were found to be, on average, lower than norm group scores (Trenerry et al., 1989; $M = 104.90$, $SD = 10.22$). However, after applying a Bonferroni correction, this difference was not found to be significant, $t(36) = -2.388$, $p = .022$, but does represent a moderate effect size, $r = 0.37$. Results did not support the stated hypothesis. Further, 14 participants fell below the identified cut-off score of 99, indicating these individuals would be designated in the brain-damaged range.

Scores of the ToL, a measure of planning ability and problem-solving, produced two variables of interest, number of excessive moves needed to complete trials and time spent before making first move across all 21 trials. There was found to be no significant difference between study participants' initial average number of excess moves across all trials ($M = 8.76$, $SD = 8.76$) compared to the norm group ($M = 8.5$), $t(36) = .179$, $p = .859$, with a small effect size, $r = 0.10$. Further, there was no significant difference between participants ($M = 6.88$, $SD = 2.06$) and the Tower of London norm group ($M = 6.575$, $SD = 3.93$) for average time before first move across all trials, $t(36) = .902$, $p = .373$, with a small effect size, $r = 0.14$. These results do not provide support for the hypothesis.

The measure of verbal fluency and communication deficits, COWA, produced two variables of interest, total number of words produced across three letters (FAS) and total number of animals named within 60 seconds. On average, study participants produced fewer words (M = 40.30, SD = 13.35) compared to reported metanorms based on education level (M = 41.14, SD = 12.37; Loonstra, Tarlow, & Sellers, 2001), $t(39) = -.398$, $p = .693$, $r = 0.06$. However, this difference was not found to be significant. Further, there was no significant difference between study participants production of animal names (M = 21.95, SD = 5.1) and norm group performance (M = 21.9, SD = 5.4), $t(39) = .062$, $p = .951$. These differences do not support hypothesis.

The LNS task was utilized to measure working memory and attentional abilities. Study participants produced lower scores on the LNS task (M = 9.45, SD = 1.93) compared to norm group mean standard score (M = 10, SD = 3). However, this difference was not found to be significant, $t(39) = -1.798$, $p = .08$, with a small effect size, $r = 0.28$, and did not support hypothesis.

Moreover, Table 12 presents information on the differences between the study sample and normative samples across measures.

Table 12. Differences between Study Sample and Normative Samples across Variables

Variable	Initial *M*	Normative *M*	*t*	*p*	1.5 SD (Perc)
BDEFS-T	195.34	133.90	6.187	.000**	
BDEFS-1	50.32	34.30	5.354	.000**	
BDEFS-2	48.29	35.99	4.182	.000**	
BDEFS-3	43.55	28.47	6.419	.000**	
BDEFS-4	29.63	15.37	8.074	.000**	
BDEFS-5	22.76	19.38	2.188	.035*	
BDEFS-SC	30.61	7.31	5.541	.000**	
LNS	9.45	10.0	-1.798	.080	2 (5.00)
COWA	40.30	41.14	-.398	.693	6 (15.00)
SNST	98.97	104.90	-2.238	.022*	8 (22.86)
CTMT	41.35	50.0	-5.44	.000**	10 (27.02)
ToL-1	8.76	8.5	.179	.859	
ToL-2	6.88	6.575	.902	.373	3 (8.12)

BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; BDEFS-1 = BDEFS Self-Management to Time; BDEFS-2 = BDEFS Self-Organization/Problem-Solving; BDEFS-3 = BDEFS Self-Restraint; BDEFS-4 = BDEFS Self-Motivation; BDEFS-5 = Self-Regulation of Emotions; BDEFS-SC = BDEFS Symptom Count; LNS = Letter-Number Sequencing Standard Score; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; 1.5 SD (Perc) = Number and Percentage of Scores 1.5 SD Below Mean; * $p < .05$ **$p < .004$ (Bonferroni-corrected p-value).

Finally, the GDS was utilized as a measure of sustained attention and impulsivity. This diagnostic tool consists of two tasks (Delay and Vigilance) with three measures of interest for which scores are classified into of three ranges (normal, borderline, and abnormal). The original normative sample statistics were unavailable for this study but the number of scores falling within diagnostic ranges are provided. For the Delay Task E.R. score, 4 individuals fell in the abnormal range, 18 in the borderline range, and 17 in the normal range. For the total correct scores on the Vigilance Task, 2 participants scored in the abnormal range, 6 in the borderline range, and 31 in the normal range. Finally, for the Vigilance Task total commission errors, 2 individuals fell into the abnormal range, 4 fell into the borderline range, and 33 in the normal range. Table 13 presents information on the distribution of GDS scores.

Table 13. Initial GDS Scores

Variable	Frequency	Percentage
Delay Task E.R.		
Normal	17	43.59
Borderline	18	46.15
Abnormal	4	10.26
Vigilance Task Total Correct		
Normal	31	79.49
Borderline	6	15.38
Abnormal	2	5.13
Vigilance Task Total Commission Errors		
Normal	34	84.62
Borderline	4	10.26
Abnormal	2	5.13

Hypothesis Three. Hypothesis Three states that participants would demonstrate significant improvements at follow-up on the LNS, COWA, CTMT, SNST, and BDEFS scores. Significant changes were not expected on the ToL and GDS tasks. In order to test these hypotheses, a series of dependent *t*-tests were conducted comparing intake and follow-up scores on all neuropsychological measures and self-report measures. To control for the number of tests performed a Bonferroni correction was applied, and an adjusted *p*-value, .003 was utilized. Table 14 presents results of this series of dependent *t*-tests.

Participants exhibited higher scores on the follow-up administration of the LNS ($M = 10.24$, $SE = .447$) compared to the initial scores ($M = 10.10$, $SE = .365$). However, this difference was not significant, $t(20) = .349$, $p = .731$, $r = .08$, indicating no clinically-relevant changes in auditory working memory performance which does not support stated hypothesis. On average, scores on verbal fluency task (COWA) were lower at intake

($M = 43.33$, $SE = 2.39$) than at follow-up testing ($M = 43.95$, $SE = 2.38$), but, again, this difference was not statistically significant, $t(20) = .421$, $p = .678$, $r = .09$. Findings do not support the study hypothesis.

Further, three variables were examined for the GDS (a measure of sustained attention). After applying a Bonferroni correction, there was no significant difference between initial ($M = .80$, $SE = .03$) and follow-up scores ($M = .87$, $SE = .02$) for the Delay Task, $t(20) = 2.135$, $p = .045$, $r = .43$, although a moderate effect size was found. At follow-up, participants exhibited a higher ability to maintain attention and inhibit impulsive responses in order to complete the task. There were no significant differences between initial ($M = 1.05$, $SE = .244$; $M = 44.10$, $SE = .22$) and follow-up scores ($M = .62$, $SE = .161$; $M = 43.71$, $SE = .448$) for commission errors, $t(20) = -1.910$, $p = .071$, $r = .39$, or total correct responses, $t(20) = -1.017$, $p = .321$, $r = .24$, respectively on the Vigilance Task. These results provide support for the hypothesis.

For the SNST, a measure of inhibitory control/response inhibition, participants exhibited significantly higher scores ($M = 108.50$, $SE = 1.43$) at follow-up than at initial testing ($M = 102.00$, $SE = 2.44$). This difference was found to be significant with a large effect size, $t(19) = 3.585$, $p = .002$, $r = .64$, and provides support for the hypothesis. In addition, study participants scored significantly higher on a measure of set-shifting, CTMT, at follow-up ($M = 49.40$, $SE = 2.57$) than at initial testing ($M = 43.20$, $SE = 1.98$), $t(19) = 3.823$, $p = .001$, $r = .66$, with a large effect size, which was hypothesized. These results show that participants' level of response inhibition and set-shifting ability improved significantly during early abstinence and participation in substance abuse treatment.

The two variables of interest for the measure of planning ability, from the ToL task, were number of excess moves and average time to first move. Participants exhibited fewer excess moves at follow-up (M = 6.00, SE = .763) than at intake (M = 6.72, SE = 1.18). This difference was not significant and provided support for the hypothesis, $t(17)$ = -.663, p = .517, r = .16. However, participants spent significantly less time, on average, planning first move at follow-up testing (M = 5.29, SE = .32) than at initial testing (M = 6.65, SE = .52), $t(17)$ = -3.889, p = .001, r = .68, with a large effect size which did not support stated hypothesis. These results suggest that participants' planning ability may have become quicker and more efficient after a period of abstinence.

Participants self-reported more EF problems at intake (M = 200.55, SE = 15.54) than at follow-up (M = 161.60, SE = 12.25), $t(19)$ = -2.923, p = .009, r = .56, with a large effect size, although this difference was not significant after applying a Bonferroni correction. They also reported having more EF symptoms at intake (M = 34.00, SE = 6.26) than at follow-up testing (M = 17.65, SE = 4.98). However, this Bonferroni-corrected difference was not significant, $t(19)$ = -2.922, p = .009, r = .56, but does represent a large effect size. These results do not provide support for the hypothesis.

In addition, participants, on average, endorsed more problems with time management (M = 49.15, SE = 4.53) at intake than at follow-up (M = 38.10, SE = 3.41). This Bonferroni-corrected difference was nonsignificant but did represent a large effect size, $t(19)$ = -2.977, p = .008, r = .56. Study participants also reported more problems with self-organization at intake (M = 54.30, SE = 4.45) than at follow-up (M = 44.95; SE = 3.70). However, this Bonferroni-corrected difference was not significant,

$t(37) = -2.794, p = .012$, but does show a large effect size, $r = .54$. These results do not support the hypothesis.

Moreover, when a Bonferroni correction is utilized, perceived self-restraint problems were not significantly higher at intake ($M = 45.30$; $SE = 3.60$) than at follow-up ($M = 36.00$; $SE = 2.47$), $t(19) = -2.917, p = .009, r = .56$, although a large effect size was observed. At initial testing, participants endorsed a higher number of problems with self-motivation and effort in work ($M = 22.60$, $SE = 2.30$) than at follow-up testing ($M = 18.65$; $SE = 1.93$). However, this difference was not found to be statistically significant, $t(19) = -1.757, p = .095, r = .37$. Further, a greater number of problems with emotional regulation were endorsed by participants at intake ($M = 29.20$, $SE = 2.58$) than at follow-up testing ($M = 23.90$; $SE = 1.81$), but the observed difference was not found to be significant, $t(19) = -1.955, p = .066, r = .41$ but does have a moderate effect size. These results do not support the stated hypothesis.

Finally, at initial testing ($M = 10.10$; $SE = 1.799$) participants endorsed a higher number of problematic personality characteristics than at follow-up ($M = 7.65$; $SE = 1.388$). However, this difference was not significant but does show a moderate effect size, $t(19) = -1.671, p = .111, r = .36$.

Table 14. Differences between Initial and Follow-up Scores across Study Variables

Variable	Initial Mean (*SE*)	Follow-Up Mean (*SE*)	*t*	*p*
BAT-37	10.10 (1.80)	7.65 (1.39)	-1.671	.111
BDEFS-T	200.55 (15.54)	161.60 (12.25)	-2.922	.009*
BDEFS-1	49.15 (4.53)	38.10 (3.41)	-2.977	.008*
BDEFS-2	54.30 (4.45)	44.95 (3.70)	-2.794	.012*
BDEFS-3	45.30 (3.60)	36.00 (2.47)	-2.917	.009*
BDEFS-4	22.60 (2.30)	18.65 (1.93)	-1.757	.095
BDEFS-5	29.20 (2.58)	23.90 (1.81)	-1.955	.066
BDEFS-SC	34.00 (6.26)	17.65 (4.97)	-2.922	.009*
LNS	10.10 (.365)	10.24 (.447)	.349	.731
COWA	43.33 (2.39)	43.95 (2.38)	.421	.678
SNST	102.00 (2.44)	108.50 (1.43)	3.585	.002**
CTMT	43.20 (1.98)	49.40 (2.57)	3.823	.001**
GDS-1	.80 (.03)	.87 (.02)	2.135	.045*
GDS-2	44.10 (.217)	43.71 (.448)	-1.017	.321
GDS-3	1.05 (.244)	.62 (.161)	-1.910	.071
ToL-1	6.72 (1.18)	6.00 (.76)	-.663	.517
ToL-2	6.65 (.52)	5.29 (.32)	-3.889	.001**

BAT-37 = Brief Assessment of Traits – 37; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; BDEFS-1 = BDEFS Self-Management to Time; BDEFS-2 = BDEFS Self-Organization/Problem-Solving; BDEFS-3 = BDEFS Self-Restraint; BDEFS-4 = BDEFS Self-Motivation; BDEFS-5 = Self-Regulation of Emotions; BDEFS-SC = BDEFS Symptom Count; LNS = Letter-Number Sequencing Standard Score; COWA = Controlled Oral Word Association Test; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-1 = Gordon Diagnostic System Delay ER; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; * $p < .05$ ** $p < .003$ (Bonferroni-corrected *p*-value).

Hypothesis Four. Hypothesis Four states that EF will be associated with duration of substance use, substance-related problems, and personality characteristics. To test Hypothesis Four, four multiple regression analyses were conducted to identify significant predictors among executive functions (GDS, LNS, ToL, COWA, SNST, CTMT), and self-report problems (BDEFS) for the following dependent variables; years of substance abuse, substance-related problems (AUDIT total and SIP-D total scores), and problematic personality traits (BAT-37 total scores). In order to control for the number of tests performed, a Bonferroni correction was used for the following multiple regression analyses and the adjusted *p*-value utilized to test for significance was .005.

Table 15 summarizes the results of the regression predicting SIP-D total score. A significant regression model with 10 predictors was found, $F(10, 22) = 10.02$, $p = .000$, with an $R^2 = .82$. Among variables examined, BDEFS Total EF Summary score ($\beta = .88$, $t(32) = 8.34$, $p = .000$) was the strongest predictor of self-report substance use problems (SIP-D). Higher self-reported EF deficits were predictive of more reported substance use problems and negative consequences related to drug use. Two additional significant predictors were number of commission errors ($\beta = .57$, $t(32) = 4.42$, $p = .004$) and total correct scores ($\beta = .43$, $t(32) = 3.18$, $p = .000$) on the Vigilance Task of the GDS indicating that more impulsive responses, and reduced visual vigilance, are associated with higher levels of negative drug-related problems. A final significant predictor of adverse consequences was CTMT performance, ($\beta = -.39$, $t(32) = -3.48$, $p = .000$), suggesting that set-shifting ability is predictive of level of substance-related problems.

Table 15. Regression Analysis Predicting SIP-D Scores

Variable	*B*	*SE B*	*β*	*t*	*p*
Constant	-145.22	51.35			
COWA	.02	.10	.02	.16	.874
LNS	-2.15	.68	-.40	-3.16	.005*
GDS-1	13.23	8.24	.16	1.61	.123
GDS-2	3.55	1.12	.43	3.18	.004**
GDS-3	3.72	.84	.57	4.42	.000**
SNST	.21	.09	.23	2.28	.033
CTMT	-.48	.14	-.39	-3.48	.002**
ToL-1	-.28	.17	-.17	-1.66	.111
ToL-2	-.53	.52	-.10	-1.02	.317
BDEFS-T	.16	.02	.88	8.34	.000**

COWA = Controlled Oral Word Association; LNS = Letter-Number Sequencing Standard Score; GDS = Gordon Diagnostic System Delay ER; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; $R^2 = .82$; $*p < .05$ $**p < .005$ (Bonferroni-corrected *p*-value).

Table 16 displays the results for the regression model predicting AUDIT total score. The regression model with 10 predictors was not found to be significant, $F(10, 22) = .592$, $p = .803$, with an $R^2 = .21$. Overall, no significant predictors for alcohol use and related problems were identified among the neuropsychological variables examined in this study.

Table 16. Regression Analysis Predicting AUDIT Scores

Variable	*B*	*SE B*	*β*	*t*	*p*
Constant	21.64	134.47			
COWA	.19	.26	.20	.74	.467
LNS	-.31	1.78	-.05	-.22	.828
GDS-1	27.43	21.57	.27	1.27	.217
GDS-2	-1.09	2.92	-.11	-.37	.713
GDS-3	-.24	2.20	-.03	-.11	.914
SNST	-.03	.24	-.03	-.12	.907
CTMT	.01	.36	.01	.01	.990
ToL-1	-.28	.44	-.14	-.63	.534
ToL-2	2.22	1.37	.34	1.63	.118
BDEFS-T	.02	.05	.10	.44	.663

COWA = Controlled Oral Word Association; LNS = Letter-Number Sequencing Standard Score; GDS = Gordon Diagnostic System Delay ER; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; $R^2 = .21$; $*p < .05$ $**p < .005$ (Bonferroni-corrected *p*-value).

Table 17 presents the results for the regression model predicting BAT-37 total score. The regression model with 10 predictors was found to be significant, $F(10, 22) = 5.77$, $p = .000$, with an $R^2 = .72$. The only significant predictor among variables for BAT-37 scores was BDEFS Total EF Summary score ($\beta = .82$, $t(32) = 6.32$, $p = .000$). Findings indicate that a higher level of self-report EF deficits was related to more identified problematic personality traits.

Table 17. Regression Analysis Predicting BAT-37 Scores

Variable	*B*	*SE B*	*β*	*t*	*p*
Constant	-101.53	47.16			
COWA	-.01	.09	-.01	-.07	.947
GDS-1	13.36	7.57	.22	1.77	.091
GDS-2	1.59	1.03	.26	1.55	.136
GDS-3	.60	.77	.12	.78	.446
SNST	.19	.09	.28	2.17	.041*
CTMT	-.15	.13	-.16	-1.19	.247
ToL-1	-.07	.15	-.05	-.42	.676
ToL-2	-.14	.48	-.04	-.29	.774
BDEFS-T	.11	.02	.82	6.32	.000**

COWA = Controlled Oral Word Association; LNS = Letter-Number Sequencing Standard Score; GDS = Gordon Diagnostic System Delay ER; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; $R^2 = .72$; $*p < .05$ $**p < .005$ (Bonferroni-corrected *p*-value).

Table 18 displays results of the multiple regression for predicting years of substance usage. The regression model with 10 predictors was not found to be significant, $F(10, 21) = .33, p = .961$, with an $R^2 = .14$. No significant predictors for years of substance usage was identified among the neuropsychological measures examined in this study.

Table 18. Regression Analysis Predicting Years of Substance Abuse

Variable	*B*	*SE B*	*β*	*t*	*p*
Constant	2.68	124.79			
COWA	.09	.24	.11	.38	.707
LNS	.61	1.65	.10	.37	.717
GDS-1	13.49	20.04	.15	.67	.508
GDS-2	-.49	2.75	-.06	-.18	.860
GDS-3	-.09	2.03	-.01	-.04	.965
SNST	-.06	.22	-.06	-.26	.798
CTMT	.15	.38	.10	.40	.691
ToL-1	.20	.45	.11	.44	.665
ToL-2	1.96	1.28	.35	1.54	.139
BDEFS-T	-.01	.05	-.05	-.22	.832

COWA = Controlled Oral Word Association; LNS = Letter-Number Sequencing Standard Score; GDS = Gordon Diagnostic System Delay ER; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; $R^2 = .14$; $*p < .05$ $**p < .005$ (Bonferroni-corrected *p*-value).

Hypothesis Five. Hypothesis Five states that cognitive functions at intake will be associated with treatment progression. To examine Hypothesis Five, a binary logistic regression analysis was performed to identify significant predictors of treatment progression, as measured by retention at follow-up testing point, among the measured executive cognitive functions at initial testing. The logistic regression model was not found to be significant, $\chi^2(10) = 14.45, p = .153$, and it explained 35.5% (Cox & Snell R^2) of the variance in treatment retention while 72.7% of cases were classified accurately. Results indicate that there were no significant predictors of treatment retention at time of follow-up testing among administered variables, including self-report EF problems, sustained attention, verbal fluency, working memory, planning ability, set-shifting ability, and response inhibition.

Table 19. Logistic Regression Analysis Predicting Treatment Retention

Variable	*B*	*SE B*	Wald	*p*	Odds Ratio
Constant	-8.26	29.49	.08	.779	.000
COWA	.06	.06	.84	.359	1.06
LNS	.41	.40	1.08	.300	1.51
GDS-1	3.22	4.03	.64	.423	25.14
GDS-2	-.02	.63	.001	.978	.983
GDS-3	-1.05	.60	3.11	.078	.35
SNST	.02	.05	.17	.680	1.02
CTMT	-.01	.06	.01	.927	.99
ToL-1	-.132	.09	2.30	.130	.88
ToL-2	.24	.32	.56	.454	1.27
BDEFS-T	-.001	.01	.02	.895	.10

COWA = Controlled Oral Word Association; LNS = Letter-Number Sequencing Standard Score; GDS = Gordon Diagnostic System Delay ER; SNST = Stroop Neuropsychological Screening Test; CTMT = Comprehensive Trail-Making Task Composite *t*-Score; GDS-2 = Vigilance Total Correct; GDS-3 = Vigilance Total Commissions; ToL-1 = Tower of London Task-Excess Moves; ToL-2 = Time to First Move; BDEFS-T = Barkley Deficits in Executive Functioning Scale-Total EF Summary Score; $R^2 = .83$; $*p < .05$ $**p < .005$ (Bonferroni-corrected *p*-value).

CHAPTER FOUR

DISCUSSION

The purpose of the present study was to examine multiple elements of executive functioning of individuals undergoing residential substance abuse treatment and to investigate the relationship between self-report EF problems and executive functioning variables, including sustained attention, verbal fluency, working memory, planning ability, set-shifting ability, and response inhibition. Further, this study investigated the performance of substance abusers on multiple measures of neurocognitive functioning when compared to established normative samples, as well as evaluating changes in functioning that occur during early abstinence while in treatment. In addition, the relationships between executive functioning and extent of substance abuse problems, identified personality problems, and treatment progression were evaluated. The project included 40 participants undergoing residential substance abuse treatment who were aged 19 to 60 years. Gender differences were minimal, therefore results are reported for the combined sample. Only one significant difference was identified across neuropsychological measures, self-report EF scales, and measure of problematic personality traits when comparing male and female subjects. Female participants reported significantly more difficulties with ability to organize thoughts and actions and create solutions to effectively problem solve compared to males.

Several significant correlations were found among executive functioning measures at initial testing, ranging from .32 to .67, which is consistent with previous research. For example, working memory scores were found to be related to sustained attention and verbal fluency, whereas set-shifting ability was associated with sustained attention, impulsivity, response inhibition, and planning ability. One interesting finding was that verbal fluency (COWA) was related to only one other variable (the fewest of any EF measure investigated) as it was positively correlated to LNS, a measure of auditory working memory. One possible explanation for these results is that LNS and COWA are the only tests studied with exclusively verbal memory and recall skills utilized while all other measures possess some visual component as well. In addition, the observed correlations support the argument that identified executive functions are related, but dissociable, cognitive processes. These results also do not indicate that substance abuse greatly alters an individual's general performance pattern across measures in relation to each other.

Further, the WASI full-scale IQ was not found to be significantly associated to any EF test utilized, although this may be related to the relatively low number of participants who were administered this measure and the observed restriction in range of scores (*SD* = 7.66). Further, planning ability, as measured by average time to first move on the ToL, was also not related to any other cognitive measure. This finding was inconsistent with previous research which has found an inverse correlation between problem errors and average first move time (Ward & Allport, 1997). Unexpectedly, number of excessive moves was not related to amount of planning time utilized before solving tasks.

Relationship between Self-Report Ratings and Neuropsychological Measures

Hypothesis One stated that self-report EF problems would be related to performance on EF tests at intake. However, the only EF test found to be related to any self-report scale was the number of correct responses on the GDS Vigilance scale which is a measure of sustained attention and impulsivity. Small to moderate negative correlations, -.26 to -.47, were found between number of correct responses and BDEFS Total EF Summary score, self-management to time, self-organization, self-motivation, and emotional self-regulation. Although only one of the Bonferroni-corrected correlation coefficients observed was significant, it is notable that the GDS Vigilance scale produced the greatest relationships across all BDEFS subscales and total score which suggests that mental vigilance and impulsivity was most closely related to identified problems with daily activities when compared to several EF tests. No other significant relationships were found between self-report EF scores (including BDEFS Total EF Summary score and five subscales) and performance on multiple neuropsychological measures (COWA, LNS, CTMT, SNST, and ToL). These findings were not completely consistent with previous research in which normative samples have exhibited significant associations, although small to moderate correlations, between subscales of the BDEFS and similar EF measures, such as Conner's Continuous Performance Task, WAIS-III Digit Span, Stroop Color-Word Interference Test, and Tower of London task (Barkley, 2011). It should be noted that absolute magnitudes of many of the correlations found in this study between BDEFS subscales and EF measures were similar to significant correlation coefficients of previous research which suggests that the present sample size may account for the lack of significant findings.

Although the BDEFS is measuring differing elements of functioning (self-management to time, self-organization/problem-solving, self-restraint, self-motivation, and self-regulation of emotions) it was expected that perceived functioning in these areas would be related to performance measures. The inconsistency between the present study and previous research may be related to the types of samples utilized. Past research studies utilized normal and ADHD-diagnosed samples while the present investigation examined substance abusers. It may be that drug usage causes a unique pattern of deficits affecting daily functioning and performance patterns on batteries of neuropsychological testing in differing ways. Further, it may be that the relatively high level of education (or general cognitive functioning) of the study sample limited the extent of deficits, in comparison to norm groups, while the BDEFS is better able to measure self-perceived reductions in functioning.

Interestingly, Barkley (2011) argues that EF rating scales, such as the BDEFS, are more predictive of problems in major life areas with higher ecological validity when compared to performance measures. This researcher suggests that results of EF rating scales provide more clinically relevant information. It appears reasonable to argue that scores on rating scales may be more accurate measures of problems completing daily tasks due to EF deficits which can directing affect goal-directed behaviors and may be useful in the clinical evaluation of individuals with substance use disorders.

Overall Performance on Neuropsychological Measures

Hypothesis Two stated that participants would exhibit significant deficits on multiple neuropsychological measures at intake to substance abuse treatment. Participants did report significant deficits in EF and daily activities across four of five subscales of the

BDEFS. They reported problems with time management, organization and problem-solving, inhibition, and impulsivity. Subjects also endorsed problems with self-motivation and ability to maintain focus. Overall, 24 of 40 participants reported EF deficits within the clinically significant or deficient ranges.

When compared to normative samples, participants exhibited significant deficits on only one of six EF tests administered. Moreover, only 8 of the 40 subjects exhibited deficits on more than 1 EF measure administered at intake. This is not consistent with previous research (Davis, Liddiard, & McMillan, 2002) which found a noticeably higher percentage of drug abusers exhibiting abnormal scores on at least two psychological measures. Similarly, Bates et al. (2002) explain that a majority of alcohol-dependent individuals display neurocognitive impairments even during abstinence. Notably, the inconsistency of the study results with past research does not appear to be related to length of abuse as the average periods of drug abuse were similar in the present study and the research of Davis et al. (2002).

Overall, study participants displayed reduced abilities in set-shifting, or cognitive flexibility, as measured by the CTMT. These results suggest impairment in the lateral frontal cortex and dorsolateral frontal cortex which are areas believed to be responsible for planning, abstract reasoning, and decision-making skills (Criaud & Boulinguez, 2013; Wilmsmeier et al., 2010). No significant problems were evident in sustained attention, impulsivity, or ability to maintain attention and manipulate information in working memory. Participants also did not exhibit deficits in verbal fluency or planning ability. These findings were not consistent with the stated hypothesis and previous research which has found deficits in substance users across multiple EF domains, including impulsivity, perseveration, decision-making, working memory, visual memory, planning ability, updating, flexibility, inhibition, and organizational skills (Dolan, et al., 2008; Ersche, et al., 2006; Parada et al., 2012; Pitel et al., 2007; Verdejo-García et al., 2010).

One explanation for these unique findings may be the clientele of this addiction facility. Previous research (Tracy & Young, 2012) has found above average intellectual functioning among patients within this facility. It may be that any impairments in functioning due to substance abuse may be moderated by premorbid intellectual and cognitive abilities. The observed, generally normal functioning may in fact be evidence of reductions in functioning from higher levels. Premorbid cognitive functioning may also affect the level and severity of usage thus impacting the overall amount of impairment caused by substance abuse. Future research should more directly consider the relationship between global intellectual functioning and EF deficits associated with substance usage. Another possible explanation for these results may be that this higher functioning sample sought treatment at the behest of others, including social support systems and professional organizations, sooner after the development of significant substance-related problems, and before more extensive cognitive damage occurred, compared to more typical substance-dependent samples.

It also should be noted that these findings may not suggest the absence of extensive EF impairments in this sample because the self-report scores indicate significant problems within multiple areas. Although no single cognitive area appears to be grossly affected by substance abuse, it may be that smaller reductions in abilities across multiple domains result in impairments in behavioral functioning which are being self-reported. Further, researchers have found a self-report measure to be more sensitive than neuropsychological tests (including the Iowa Gambling Task and Stroop) in identifying EF problems and differentiating a substance use disorder group from a control group (Hagen et al., 2016). These results support the utility of self-report measures in assessing neurocognitive functioning of individuals receiving substance abuse treatment. However, it is also possible that participants reported their EF problems experienced during substance usage and the results of neuropsychological testing represent more current, and average, functioning.

Changes in Neuropsychological Performance during Abstinence

Hypothesis Three stated that participants would exhibit improvements in cognitive functioning after the cessation of drug usage and a period of abstinence within substance abuse treatment. Initially, investigators planned to use days of abstinence prior to initial evaluation as a covariate within a series of ANCOVA procedures. However, number of clean days was not found to be associated with performance on administered measures. Thus a series of dependent samples *t*-tests were conducted in lieu of ANCOVAs.

Results for this hypothesis indicated significant improvements for only three cognitive measures administered (SNST, CTMT, and ToL). Participants exhibited significantly better performances at follow-up on measures of inhibitory control (SNST) and set-shifting abilities (CTMT) after approximately 45 days of treatment. These findings are especially important when considering the cognitive processes likely critical in the decision-making process involved in stopping problematic substance usage and maintaining abstinence. Set-shifting, or cognitive flexibility, is necessary in both completing identified therapy tasks, such as twelve-step treatment program assignments, and appropriately shifting attention to more relevant stimuli or information, such as considering motivation or reasons to refrain from substance use, when performing cost–benefit analyses of usage. Deficits in cognitive flexibility can result in perseverance and difficulty effectively considering alternative behavioral options, such as when an individual experiences an urge to relapse. Cognitive flexibility is necessary in both taking various perspectives when problem-solving and in recognizing that a behavioral response utilized is ineffectual. Likewise, response inhibition involves the suppression of automatic responses to stimuli, such as substance use due to physiological, psychological, or environmental cues. Moreover, problems with cognitive flexibility and response inhibition can negatively affect problem-solving which may lead to increased frustration, distress, and likelihood of relapse to substance usage. Further, Blume and Marlatt (2009) suggest that the utilization of more behavioral therapy techniques, as opposed to cognitive techniques, may be beneficial early in substance abuse treatment due to such deficits in EF.

Moreover, participants spent significantly less planning time, on average, before each initial move on trials of the ToL at follow-up testing. These results likely do not indicate reduced planning ability or deliberativeness, nor increased impulsivity during abstinence. Conversely, reduced planning time may indicate increasing levels of effectiveness and efficiency in planning. As Berg and Byrd (2002) explain, initial planning time may be interpreted in two ways as it increases, either adaptive deliberativeness in planning or ineffective planning ability and difficulty in developing a course of action. It appears likely that participants became more efficient in completing this task after several weeks of abstinence, and this suggests some level of cognitive recovery and improvement in problem-solving skills.

In addition, these findings were not consistent with results of other research which has found improvements within weeks of abstinence for substance abusers within the areas of working memory, information processing speed, and verbal fluency (Bates, Voelbel, Buckman, Labouvie, & Barry, 2005; Manning et al., 2008; Rapeli et al., 2006).

Overall, when considering possible explanations for the lack of significant improvements at follow-up, it may be that few major changes were identified because initially participants exhibited significant deficits in only a limited number of domains as performance in most cognitive areas fell within the average ranges. Interestingly, the sample also reported fewer EF problems overall and in the areas of time management, self-organization, problem-solving, and impulsive behavior at follow-up testing. Although the observed Bonferroni-corrected differences between initial and follow-up BDEFS and subscale scores were not significant, large effects sizes were found in each domain which suggests that a larger sample size may produce statistically significant results.

Predictors of Personality Characteristics and Severity of Substance Usage

Hypothesis Four stated that measures of EF would be predictive of problematic personality characteristics, substance-related problems, and years of substance usage. Three EF measures were found to be related to level of substance-related problems, as measured by the SIP-D. Performance across multiple tests was not associated with scores on the AUDIT. Impulsivity and sustained attention, as measured by the Vigilance Task of the GDS, and mental set-shifting were predictive of level of negative factors on the

SIP-D, such as physical, social, intrapersonal, impulse control, and interpersonal problems associated with drug usage.

Interestingly, previous research has found that severity of drug usage and dependence are related to greater impairment in updating and set-shifting abilities, as well as increased perseverative errors, which was not observed in this study (Lyvers & Yakimoff, 2003; Verdejo-García & Pérez-García, 2007). Although this sample exhibited deficits in set-shifting ability (CTMT scores), these scores were not associated with drug use severity/problems. Further, self-report EF deficits were predictive of SIP-D scores but not AUDIT scores. Problems in areas such as time management, emotional regulation, self-restraint, and level of effort were predictive of drug-related problems across multiple domains. These findings may be explained by the fact that the SIP-D items are more similar to BDEFS items than the AUDIT in that questions are assessing impulse control and interpersonal problems while AUDIT questions are primarily focused on usage patterns.

Years of substance usage, as measured by self-report years of abuse of drug of choice, was also unrelated to self-report EF problems or neuropsychological performance on EF measures. Previous research in this area has shown varying results. Loeber et al. (2009) found increased problems with working memory and attention were associated with more years of alcohol dependence. However, other researchers have found years of usage for opiates and amphetamines was not related to severity of EF impairment (Ersche et al., 2006). One could conclude that type of substance may mediate the relationship between length of usage and level of cognitive impairment and types of deficits observed.

Likewise no EF tests were associated with level of problematic personality problems. These results were not expected as personality problems are commonly observed in substance abusing samples as these individuals are four times more likely to be diagnosed with a personality disorder than healthy controls (Armstrong & Costello, 2002). Further, previous research examining the comorbidity of personality disorders and substance abuse has estimated that approximately 19% of individuals with at least one personality disorder will experience drug dependence and 42% will experience lifetime alcohol dependence, with rates even higher for certain disorders such as antisocial personality disorder and borderline personality disorder (Trull, Jahng, Tomko, Wood, & Sher, 2010). Moreover, neuroticism, obsessive compulsive personality traits, and borderline personality disorder have been found to be associated with EF deficits, including problems in planning, fluency, sustained attention, and working memory (García-Villamisar & Dattilo, 2015; Gvirts et al., 2012; Schretlen et al., 2010).

The regression model conducted isolated only one significant predictor of perceived personality problems. Findings indicated that a higher level of self-report EF deficits was related to more identified problematic personality traits, and these results provide support for previous research which has found personality disorders to be related to EF problems. These findings were expected as several EF deficits measured, such as impulsivity, lack of motivation/effort, reduced self-restraint, and irregulated emotions, appear closely related to multiple characteristics of personality disorders, such as emotional instability, impulsive/reckless behaviors, irritability, consistent irresponsibility, and instability in goals. Overall, these results again may be related to the generally average performance of the sample on the neuropsychological tests administered.

Predictors of Treatment Retention

Hypothesis Five stated that neuropsychological measures would be predictive of treatment retention at testing follow-up (approximately 45 days after initial testing). Previous research has found reduced treatment retention to be significantly related to EF deficits. Verdejo-García et al. (2012) found lower scores on an EF measure of one's ability to multitask and organize sub-goals predictive of fewer days in treatment. Further, performance on the Stroop Color-Word Interference Test, inhibitory control, perseverative errors, attention, mental speed, and spatial ability have been found to significantly predict treatment completion among samples of individuals receiving outpatient substance abuse treatment (Aharonovich et al., 2006; Streeter et al., 2008).

Results of this study found no neuropsychological measures predictive of treatment retention. Moreover, self-report EF problems also were not associated with treatment retention. One explanation of these findings may be the overall neuropsychological performance of the sample. As previously described, participants within this study did not exhibit the level of deficits frequently observed in studies of neuropsychological performance of substance abusers. The fact that the current study examines residential treatment (as opposed to outpatient treatment assessed in similar research) and includes 25% of participants receiving treatment in order to maintain their current work status, may also have impacted study findings related to treatment retention.

Study Strengths and Limitations

This section will consider possible strengths and limitations of the present study and potentially impactful future research directions. One strength of this study was the extensive neuropsychological battery utilized which assessed a variety of executive functions critical to daily functioning, including set-shifting, working memory, response inhibition, sustained attention, impulsivity, verbal fluency, and planning ability. Notably, when examining the pattern of performance in relation to the test administration order, there was no indication of response fatigue. Further, the inclusion of a self-report EF rating scale is uncommon in similar research studies. The utilization of a residential program treating a relatively unique clientele could be considered to be both a strength and weakness of this study. Since this sample is likely to be noticeably different from many similar studies which utilize community and government-related addiction treatment facilities, findings may aid in the development of treatment plans for similar clients seeking treatment. However, given the ethnic composition, level of education, and career backgrounds of the participants, findings should be cautiously generalized when considering other groups of substance-abusing individuals. The present research project also possesses multiple limitations which may have impacted the results and interpretative conclusions. Firstly, the participant pool was comprised of nearly all Caucasians (95%) which greatly differs from the current U.S. population. Further, subjects were recruited from only one private treatment facility within the Southern U.S. which limits the availability of potential participants eligible for this study. The sample also consisted of 60% college graduates and 87.5% of individuals had at least some college experience while participants who were administered the WASI exhibited a mean FSIQ of 106. These characteristics are noticeably different from national statistics because approximately 36.2% of adults between 25 and 64 years of age have earned a degree beyond secondary education (United States Department of Education National Center for Education Statistics, 2015).

Further, due to the clientele of the private addiction treatment facility utilized, at least 25% of the sample were professionals, such as medical and legal professionals, referred to treatment in order to maintain their employment status. Increased ethnic and socioeconomic diversity and investigation in various types of treatment facilities would likely improve future research examining deficits in executive cognitive functioning and its association to treatment response for substance abusing individuals.

In addition, likely the most problematic limitation of the study was the overall sample size of 40 participants, with 21 of those being retested at follow-up. Due to multiple issues recruiting subjects, the number of participants assessed was reduced after testing began. The final number of participants included may have reduced the power of the study to detect significant findings, and researchers' capacity to identify neurocognitive deficits and improvement may have been affected. The number of participants studied also limited researchers' ability to consider any potential differences in performance based on individuals' substance of choice. Moreover, study results may have been affected by the fact that certain variables were based on self-report measures, and even though participants were directly informed that results would not be shared with facility staff or affect treatment status, responses may have been influenced by the treatment setting.

An additional limitation to the study was the inability to assess the reason for early treatment cessation for many participants. This data may have helped to elucidate the impact of neuropsychological functioning on treatment response. Future research should attempt to follow-up with participants in order to better understand what, if any, relationship that may exist between EF and treatment completion/response.

Future Research

Ongoing research investigating neuropsychological deficits related to substance abuse should continue to examine more unique samples such as this study which included individuals with generally higher levels of education and intellectual ability. Further, research should continue to explore how neurocognitive functioning is related to, and influences an individual's response to treatment and recovery process. Research may benefit from including clinician ratings of patients' treatment participation and progress. Investigating how performance on neuropsychological measures are related to observer ratings may help to better understand how EF deficits impact recovery from substance use disorders and ongoing abstinence.

Additional research considering the utility of self-report measures of functioning may also be vital. If more fully shown to be valid assessments of functioning for individuals with substance use disorders, then self-report measures may be a less expensive, less time consuming, and more efficient means of identifying individuals with severe cognitive deficits which could impact treatment planning and response. This is especially important when considering the influence of insurance and managed health care companies on the access to, and duration/type of, treatment available to many individuals.

Further, a comparison of participants' neuropsychological functioning and response to treatment based on drug of choice may be especially beneficial in further understanding and effectively treating substance use disorders. Previous research has considered differences in cognitive performance across certain drugs of choice (Ersche et al., 2006; Sclafani et al., 2002). However, minimal research has attempted to examine how EF patterns change during abstinence and how this may impact treatment success. Increased usage of longitudinal studies appears necessary in order to more fully investigate EF predictors of treatment response and effective treatment interventions for individuals identified with EF deficits. Of particular utility may be longitudinal studies examining premorbid cognitive and executive functioning in order to better understand the neurocognitive effects of substance usage and subsequent cognitive recovery during abstinence.

APPENDIX A

HUMAN SUBJECTS CONSENT FORMS

HUMAN SUBJECTS CONSENT FORM

The following is a brief summary of the project in which you are asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT: Examining the Relationship between Executive Functioning and Substance Abuse -Part 1.

PURPOSE OF STUDY/PROJECT: The purpose of the present study is to examine the relationship between executive functioning and substance abuse. Further, the association between executive functioning and response to substance abuse treatment will be investigated.

PROCEDURE: Prior to participation, you must sign an informed consent. By providing your informed consent, you will be granting the researchers access to the results from certain questionnaires and tests administered by Palmetto Addiction Recovery Center (PARC) staff.

INSTRUMENTS: The only measures which the researchers will have access to are the Brief Assessment of Traits-37, Comprehensive Trail-Making Task, Stroop Neuropsychological Screening Test, and Wechsler Abbreviated Scale of Intelligence.

RISKS/ALTERNATIVE TREATMENTS: The participant understands that Louisiana Tech is not able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

BENEFITS/COMPENSATION: You will not be compensated for participating in this study.

I, ____________________, attest with my signature that I have read and understood the following description of the study, "Examining the Relationship between Executive Functioning and Substance Abuse," and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Palmetto Addiction Recovery Center in any way. Further, I understand that I may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my measures will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

_________________________________ ______________

Signature of Participant or Guardian **Date**

CONTACT INFORMATION: The principal experimenters listed below may be reached to answer questions about the research, subjects' rights, or related matters.

PROJECT DIRECTOR(S): John Tracy, M.A., and Tony Young, Ph.D.
PHONE: 318-257-5066; 318-257-2449

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters: Dr. Stan Napper (257-3056) or Dr. Mary M. Livingston (257-2292 or 257-5066)

HUMAN SUBJECTS CONSENT FORM

The following is a brief summary of the project in which you are asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT Examining the Relationship between Executive Functioning and Substance Abuse-Part 2.

PURPOSE OF STUDY/PROJECT: The purpose of the present study is to examine the relationship between executive functioning and substance abuse. Further, the association between executive functioning and response to substance abuse treatment will be investigated.

PROCEDURE: Prior to participation, you must sign an informed consent. After your consent form is signed, you will be asked to complete a questionnaire which will take about 15 minutes. You also will be asked to complete four neuropsychological tasks which will take about 40 minutes. Please answer the questions truthfully and to the best of your ability. In approximately two months, you will be asked to complete part of the initial questionnaire and complete the same neuropsychological tasks again which will take about 70 minutes. During the fourth and eighth weeks of treatment, your primary counselor will be asked to complete a questionnaire concerning your progress and engagement in treatment.

INSTRUMENTS: The questionnaires contain multiple surveys which include questions about your background and history, substance-related problems, and cognitive problems such as poor attention or memory. The neuropsychological tasks will primarily measure your executive functions, such as working memory, attention, and planning ability. The Clinician Patient Rating Scale completed by your counselor will measure your participation and progress in treatment.

RISKS/ALTERNATIVE TREATMENTS: The participant understands that Louisiana Tech is not able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

BENEFITS/COMPENSATION: You will not be compensated for participating in this study.

Before providing your informed consent and signing below please check the following boxes indicating that you understand the procedures of this study.

☐

I understand that I will be administered additional measures that are not part of the standard assessment battery of PARC.

☐

I understand that I am giving the researcher permission to contact my primary counselor concerning my treatment progress.

I, ________________, attest with my signature that I have read and understood the following description of the study, "Examining the Relationship between Executive Functioning and Substance Abuse," and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Palmetto Addiction Recovery Center in any way. Further, I understand that I may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my measures will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

______________________________ ____________

Signature of Participant or Guardian **Date**

CONTACT INFORMATION: The principal experimenters listed below may be reached to answer questions about the research, subjects' rights, or related matters.
John Tracy, M.A., Tony Young, Ph.D. **PHONE:** 318-257-5066; 318-257-2449

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:
Dr. Stan Napper (257-3056) or Dr. Mary M. Livingston (257-2292 or 257-5066)

APPENDIX B

DEMOGRAPHIC QUESTIONNAIRE

Demographic Questionnaire

Please do not put your name or any other identifying information on any of the provided survey materials. Please answer all questions as truthfully as possible. Circle the answer which best describes you.

Directions: Please answer the following questions by filling in the blank or circling the appropriate answer

Age: __________ Sex: 1. Male 2. Female

With which ethnic group do you most identify?
1. African-American 2. Asian-American 3. Caucasian
4. Hispanic/Latin 5. Native American 6. Other:__________________

Spirituality:
1. Not at all spiritual 2. Not very spiritual 3. Somewhat spiritual 4. Very spiritual

Church Involvement:
1. Very involved (attend church events more than once a week)
2. Involved (attend at least once a week)
3. Slight involvement (attend church events occasionally)
4. No involvement

Religious Persuasion:
1. Atheist (do not believe in God) 2. Unsure of religious beliefs 3. Religious

Parental status during majority of childhood:
1. Two parents
2. Single parent
3. Extended family (grandparent, aunt, other)
4. Parents and extended family
5. Adopted parents

Highest level of education completed:
1. Elementary 2. Middle School 3. High School Diploma or GED
4. Some college experience 5. College Degree

Why are you entering into this program?
1. You are tired of your current situation and believe you need help to change things
2. Your family has pressured you into participating in some type of treatment
3. You have been ordered to participate by a court, lawyer, OCS, or government agency
4. You are participating in order to keep your job or because of employer suggestion
5. Other

Substance	Past 30 Days		Life-time Years	
1 Alcohol – Any use at all				
2 Alcohol – To Intoxication				
3 Heroin				
4 Methadone				
5 Other opiates/analgesics				
6 Barbiturates				
7 Other sed/hyp/tranq.				
8 Cocaine				
9 Amphetamines				
10 Cannabis				
11 Hallucinogens				
12 Inhalants				

How many days since your last substance (alcohol/drug usage)? ____________________

Which substance is the major problem/drug of choice? ____________________

Please code as above or 00-No Problem.

APPENDIX C

HUMAN USE COMMITTEE APPROVAL FORM

LOUISIANA TECH
UNIVERSITY

OFFICE OF UNIVERSITY RESEARCH

MEMORANDUM

TO: Dr. Tony Young, Dr. Walter Buboltz and Mr. John Tracy

FROM: Dr. Stan Napper, Vice President Research & Development

SUBJECT: Human Use Committee Review

DATE: July 30, 2015

RE: Approved Continuation of Study HUC 1148

TITLE: **"Examining the Relationship between Executive Functioning and Substance Abuse"**

HUC 1148

The above referenced study has been approved as of July 30, 2015 as a continuation of the original study that received approval on January 23, 2015. **This project will need to receive a continuation review by the IRB if the project, including collecting or analyzing data, continues beyond July 30, 2016.** Any discrepancies in procedure or changes that have been made including approved changes should be noted in the review application. Projects involving NIH funds require annual education training to be documented. For more information regarding this, contact the Office of University Research.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study. If changes occur in recruiting of subjects, informed consent process or in your research protocol, or if unanticipated problems should arise it is the Researchers responsibility to notify the Office of Research or IRB in writing. The project should be discontinued until modifications can be reviewed and approved.

If you have any questions, please contact Dr. Mary Livingston at 257-5066.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM

P.O. BOX 3092 • RUSTON, LA 71272 • TEL: (318) 257-5075 • FAX: (318) 257-5079

AN EQUAL OPPORTUNITY UNIVERSITY

REFERENCES

Aharonovich, E., Hasin, D., Brooks, A., Liu, X., Bisaga, A., & Nunes, E. (2006). Cognitive deficits predict low treatment retention in cocaine dependent patients. *Drug and Alcohol Dependence*, *81*(3), 313-322. doi:10.1016/j.drugalcdep.2005.08.003

Almeida, T., & Monteiro, L. (2014). Executive functions and decision making regarding drug addicts in abstinence. *Acta Neuropsychologica*, *12*(4), 387-400.

Alterman, A., Cacciola, J., Ivey, M., Habing, B., & Lynch, K. (2009). Reliability and validity of the Alcohol Short Index of Problems and a newly constructed Drug Short Index of Problems. *Journal of Studies on Alcohol and Drugs*, *70*(2), 304-307.

Alvarez, J., & Emory, E. (2006). Executive function and the frontal lobes: A meta-analytic review. *Neuropsychology Review*, *16*(1), 17-42.

Armstrong, T. D., & Costello, E. J. (2002). Community studies on adolescent substance use, abuse, or dependence and psychiatric comorbidity. *Journal of Consulting and Clinical Psychology*, *70*(6), 1224-1239. doi:10.1037/0022-006X.70.6.1224

Aytaclar, S., Kirisci, L., Tarter, R., & Lu, S. (1999). Association between hyperactivity and executive cognitive functioning in childhood and substance use in early adolescence. *Journal of the American Academy of Child and Adolescent Psychiatry*, *38*(2), 172-178. doi:10.1097/00004583-199902000-00016

Babor, T. F., De la Fuente, J. R., Saunders, J., Grant, M. (1989). *AUDIT. The Alcohol Use Disorder Identification Test: Guidelines for use in primary health care.* Geneva: World Health Organization, Division of Mental Health.

Babor, T. F., Higgins-Biddle, J. C., Saunders, J. B., & Monteiro, M. G. (2001). *AUDIT. The Alcohol Use Disorder Identification Test: Guidelines for use in primary health care (2nd ed.).* Geneva: World Health Organization, Department of Mental Health and Substance Dependence.

Baddeley, A. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology: Section A, 49*(1), 5-28. doi:10.1080/027249896392784

Barkley, R. A. (2001). The executive functions and self-regulation: An evolutionary neuropsychological perspective. *Neuropsychology Review, 11*(1), 1-29. doi:10.1023/A:1009085417776

Barkley, R. A. (2011). *Barkley Deficits in Executive Functioning Scale (BDEFS),* New York, NY: Guilford Press.

Bates, M. E., Bowden, S. C., & Barry, D. (2002). Neurocognitive impairment associated with alcohol use disorders: Implications for treatment. *Experimental and Clinical Psychopharmacology, 10*(3), 193-212.

Bates, M. E., Voelbel, G. T., Buckman, J. F., Labouvie, E. W., & Barry, D. (2005). Short-term neuropsychological recovery in clients with substance use disorders. *Alcoholism: Clinical and Experimental Research, 29*(3), 367-377. doi:10.1097/01.ALC.0000156131.88125.2A

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50*(1-3), 7-15.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologica, 39,* 376-389. doi:10.1016/S0028-3932(00)00136-6

Beglinger, L. J., Gaydos, B., Tangphao-Daniels, O., Duff, K., Kareken, D. A., Crawford, J., & ... Siemers, E. R. (2005). Practice effects and the use of alternate forms in serial neuropsychological testing. *Archives of Clinical Neuropsychology, 20,* 517-529. doi:10.1016/j.acn.2004.12.003

Belin, D., Mar, A. C., Dalley, J. W., Robbins, T. W., & Everitt, B. J. (2008). High impulsivity predicts the switch to compulsive cocaine-taking. *Science, 5881.* 1352-1355.

Benton, A. L., de Hamsher, S. K., & Sivan, A. B. (1994). *Multilingual aphasia examination* (3rd ed.). Iowa City: AJA Associates.

Berg, W., & Byrd, D. L. (2002). The Tower of London spatial problem-solving task: Enhancing clinical and research implementation. *Journal of Clinical and Experimental Neuropsychology, 24*(5), 586-604.

Blume, A., & Marlatt, G. (2009). The role of executive cognitive functions in changing substance use: What we know and what we need to know. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine, 37*(2), 117-125. doi:10.1007/s12160-009-9093-8

Blume, A., Schmaling, K., & Marlatt, G. (2005). Memory, executive cognitive function, and readiness to change drinking behavior. *Addictive Behaviors*, *30*(2), 301-314. doi:10.1016/j.addbeh.2004.05.019

Bridgett, D., Oddi, K., Laake, L., Murdock, K., & Bachmann, M. (2013). Integrating and differentiating aspects of self-regulation: Effortful control, executive functioning, and links to negative affectivity. *Emotion, 13*(1), 47-63. doi:10.1037/a0029536

Brunelle, C., & Flood, M. (2016). Examining the relationship between self-reported executive cognitive functioning and substance misuse in university students. *Journal of Substance Use*, *21*(1), 3-8. doi:10.3109/14659891.2014.884175

Bugg, J. M., Zook, N. A., DeLosh, E. L., Davalos, D. B., & Davis, H. P. (2006). Age differences in fluid intelligence: Contributions of general slowing and frontal decline. *Brain and Cognition, 62*, 9-16.

Burzynska, A. Z., Nagel, I. E., Preuschhof, C., Gluth, S., Baeckman, L., Li, S., & ... Heekeren, H. R. (2012). Cortical thickness is linked to executive functioning in adulthood and aging. *Human Brain Mapping, 33*(7), 1607-1620.

Claes, L., Van den Eynde, F., Guillaume, S., Vogels, C., & Audenaert, K. (2012). Executive functioning in borderline personality disorder with and without self-harming behaviors. In A. M. Columbus (Ed.), *Advances in psychology research (Vol 89)* (pp. 177-184). Hauppauge, New York: Nova Science Publishers.

Clark, C. C., Pritchard, V. E., & Woodward, L. J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology*, *46*(5), 1176-1191.

Colombetti, G. (2008). The Somatic Marker Hypotheses, and what the Iowa Gambling Task does and does not show. *British Journal for the Philosophy of Science, 59*(1), 51-71. doi:10.1093bjps.axm045

Cottone, J., Drucker, P., & Javier, R. A. (2007). Predictors of moral reasoning: Components of executive functioning and aspects of religiosity. *Journal for the Scientific Study of Religion, 46*(1), 37-53. doi:10.1111/j.1468-5906.2007.00339.x

Crews, F. T., Buckley, T., Dodd, P. R., Ende, G., Foley, N., Harper, C., & ... Sullivan, E. V. (2005). Alcoholic neurobiology: Changes in dependence and recovery. *Alcoholism: Clinical and Experimental Research, 29*(8), 1504-1513. doi:10.1097/01.alc.0000175013.50644.61

Criaud, M., & Boulinguez, P. (2013). Review: Have we been asking the right questions when assessing response inhibition in go/no-go tasks with fMRI? A meta-analysis and critical review. *Neuroscience and Biobehavioral Reviews, 37,* 11-23. doi:10.1016/j.neubiorev.2012.11.003

Damasio, A. R., Tranel, D., & Damasio, H. C. (1991). Somatic markers and the guidance of behavior: Theory and preliminary testing. In H. S. Levin, H. M. Eisenberg, & A. L. Benton (Eds.), *Frontal lobe function and dysfunction* (pp. 217-229). New York: Oxford University Press.

Davis, P. E., Liddiard, H., & McMillan, T. M. (2002). Neuropsychological deficits and opiate abuse. *Drug and Alcohol Dependence, 67*(1), 105-108. doi:10.1016/S0376-8716(02)00012-1

Day, A., Metrik, J., Spillane, N., & Kahler, C. (2013). Working memory and impulsivity predict marijuana-related problems among frequent users. *Drug and Alcohol Dependence, 131* (1-2), 171-174. doi:10.1016/j.drugalcdep.2012.12.016

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135-168. doi:10.1146/annurev-psych-113011-143750

Dolan, S. L., Bechara, A., & Nathan, P. E. (2008). Executive dysfunction as a risk marker for substance abuse: The role of impulsive personality traits. *Behavioral Sciences & the Law, 26*(6), 799-822.

Duke, L., & Kaszniak, A. (2000). Executive control functions in degenerative dementias: A comparative review. *Neuropsychology Review, 10*(2), 75-99.

Dunkin, J. J., Leuchter, A. F., Cook, I. A., Kasl-Godley, J. E., Abrams, M., & Rosenberg-Thompson, S. (2000). Executive dysfunction predicts nonresponse to fluoxetine in major depression. *Journal of Affective Disorders, 60*(1), 13-23.

Ersche, K., Clark, L., London, M., Robbins, T., & Sahakian, B. (2006). Profile of executive and memory function associated with amphetamine and opiate dependence. *Official Publication of the American College of Neuropsychopharmacology, 31*(5), 1036-1047.

Fals-Stewart, W. (1997). Ability of counselors to detect cognitive impairment among substance-abusing patients: An examination of diagnostic efficiency. *Experimental and Clinical Psychopharmacology, 5*(1), 39-50. doi:10.1037/1064-1297.5.1.39

Fein, G., Torres, J., Price, L. J., & Sclafani, V. (2006). Cognitive performance in long-term abstinent alcoholic individuals. *Alcoholism Clinical and Experimental Research, 30*(9), 1538-1544.

Fernández-Serrano, M., Pérez-García, M., Schmidt Río-Valle, J., & Verdejo-García, A. (2010). Neuropsychological consequences of alcohol and drug abuse on different components of executive functions. *Journal of Psychopharmacology, 24*(9), 1317-1332.

Fillmore, M., Rush, C., & Hays, L. (2006). Acute effects of cocaine in two models of inhibitory control: Implications of non-linear dose effects. *Addiction, 101*(9), 1323-1332.

Fontes, M., Almeida, P., Bressan, R., Bolla, K., Cunha, P., Jungerman, F., & ... Lacerda, A. (2011). Cannabis use before age 15 and subsequent executive functioning. *British Journal of Psychiatry, 198*(6), 442-447. doi:10.1192/bjp.bp.110.077479

Friendly, M. (2012). SAS macro program: Power analysis for ANOVA designs [Computer software]. Retrieved from http://www.math.yorku.ca/SCS/Online/power/

Gansler, D. A., Harris, G. J., Oscar-Berman, M., Streeter, C., Lewis, R. F., Ahmed, I., & Achong, D. (2000). Hypoperfusion of inferior frontal brain regions in abstinent alcoholics: A pilot SPECT study. *Journal of Studies on Alcohol, 61*(1), 32-37.

García-Villamisar, D., & Dattilo, J. (2015). Executive functioning in people with obsessive-compulsive personality traits: Evidence of modest impairment. *Journal of Personality Disorders, 29*(3), 418-430. doi:10.1521/pedi_2013_27_101

Gerra, G., Calbiani, B., Zaimovic, A., Sartori, R., Ugolotti, G., Ippolito, L., & ... Fontanesi, B. (1998). Regional cerebral blood flow and comorbid diagnosis in abstinent opioid addicts. *Psychiatry Research, 83*(2), 117-126.

Giancola, P., Godlaski, A., & Roth, R. (2012). Identifying component-processes of executive functioning that serve as risk factors for the alcohol-aggression relation. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors, 26*(2), 201-211. doi:10.1037/a0025207

Giancola, P. R., & Tarter, R. E. (1999). Executive cognitive functioning and risk for substance abuse. *Psychological Science, 10*(3), 203-205.

Giedd, J. N. (2004). Structural magnetic resonance imaging of the adolescent brain. *Annals New York Academy of Sciences, 1021*, 77-85.

Godlaski, A., & Giancola, P. (2009). Executive functioning, irritability, and alcohol-related aggression. *Psychology of Addictive Behaviors, 23*(3), 391-403. doi:10.1037/a0016582

Goldberg, E. (2002). *The executive brain: Frontal lobes and the civilized mind.* New York: Oxford University Press.

Goldberg, E. (2009). *The new executive brain: Frontal lobes in a complex world.* New York: Oxford University Press.

Golub, S. A., Starks, T. J., Kowalczyk, W. J., Thompson, L. I., & Parsons, J. T. (2012). Profiles of executive functioning: Associations with substance dependence and risky sexual behavior. *Psychology of Addictive Behaviors, 26*(4), 895-905. doi:10.1037/a0029034

Gordon, M. (1988). *Instruction manual for the Gordon Diagnostic System, Model III.* New York: Gordon Systems, Inc.

Guerra, D., Sole, A., Cami, J., & Tobena, A. (1987). Neuropsychological performance in opiate addicts after rapid detoxification. *Drug and Alcohol Dependence*, *20*(3), 261-270.

Gvirts, H. Z., Harari, H., Braw, Y., Shefet, D., Shamay-Tsoory, S. G., & Levkovitz, Y. (2012). Executive functioning among patients with borderline personality disorder (BPD) and their relatives. *Journal of Affective Disorders*, *143*(1-3), 261-264.

Hagen, E., Erga, A. H., Hagen, K. P., Nesvag, S. M., McKay, J. R., Lundervold, A. J., & Walderhaug, E. (2016). Assessment of executive function in patients with substance use disorder: A comparison of inventory- and performance-based assessment. *Journal of Substance Abuse Treatment*, *66*, 1-8. doi:10.1016/j.jsat.2016.02.010

Hancock, M., Tapscott, J. L., & Hoaken, P. N. (2010). Role of executive dysfunction in predicting frequency and severity of violence. *Aggressive Behavior*, *36*(5), 338-349.

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences*, *16*(3), 174-180. doi:10.1016/j.tics.2012.01.006

Holler, K., & Kavanaugh, B. (2012). Physical aggression, diagnostic presentation, and executive functioning in inpatient adolescents diagnosed with mood disorders. *Child Psychiatry and Human Development*, *44*(4), 573-581. doi: 10.1007/s10578-012-0351-9

Kaller, C. P., Unterrainer, J. M., & Stahl, C. (2012). Assessing planning ability with the Tower of London task: Psychometric properties of a structurally balanced problem set. *Psychological Assessment, 24*(1), 46-53. doi:10.1037/a0025174

Katz, E. C., King, S. D., Schwartz, R. P., Weintraub, E., Barksdale, W., Robinson, R., & Brown, B. S. (2005). Cognitive ability as a factor in engagement in drug abuse treatment. *The American Journal of Drug and Alcohol Abuse, 31*(3), 359-369. doi:10.1081/ADA-200056767

Kaufman, M. J., Levin, J. M., Maas, L. C., Kukes, T. J., Villafuerte, R. A., & … Dostal, K. (2001). Cocaine-induced cerebral vasoconstriction differs as a function of sex and menstrual cycle phase. *Biological Psychiatry, 49*, 774–781.

King, R., & Best, D. (2011). Cognitive functioning and cognitive style among drug users in maintenance substitution treatment. *Drugs: Education, Prevention, and Policy, 18*(2), 132-139.

Knouse, L. E., Barkley, R. A., & Murphy, K. R. (2013). Does executive functioning (EF) predict depression in clinic-referred adults?: EF tests vs. rating scales. *Journal of Affective Disorders, 145*(2), 270-275.

Koelega, H. S. (1993). Stimulant drugs and vigilance performance: A review. *Psychopharmacology, 111*, 1–16.

Langner, R., & Eickhoff, S. B. (2013). Sustaining attention to simple tasks: A meta-analytic review of the neural mechanisms of vigilant attention. *Psychological Bulletin, 139*(4), 870-900. doi:10.1037/a0030694

Lezak, M. D. (1995). *Neuropsychological Assessment* (3rd ed.). New York: Oxford University Press.

Lezak, M., Howieson, D. B., Loring, D. W. (2004). *Neuropsychological Assessment* (4th ed.). New York: Oxford University Press.

Loeber, S., Vollstadt-Klein, S., von der Goltz, C., Flor, H., Mann, K., & Kiefer, F. (2009). Attentional bias in alcohol-dependent patients: The role of chronicity and executive functioning. *Addiction Biology, 14*(2), 194-203. doi:10.1111/j.1369-1600.2009.00146.x

Loonstra, A. S., Tarlow, A. R., & Sellers, A. H. (2001). COWAT metanorms across age, education, and gender. *Applied Neuropsychology, 8*(3), 161-166.

Lundqvist, T. (2005). Cognitive consequences of cannabis use: Comparison with abuse of stimulants and heroin with regard to attention, memory and executive functions. *Pharmacology Biochemistry and Behavior, 81*(2), 319-330.

Lyvers, M., & Yakimoff, M. (2003). Neuropsychological correlates of opioid dependence and withdrawal. *Addictive Behaviors, 28*(3), 605-611.

Mackin, R., Horner, M., Harvey, R., & Stevens, L. (2005). The relationship between neuropsychological measures and employment problems in outpatients with substance abuse. *Rehabilitation Psychology, 50*(2), 158-163.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109*, 163–203.

Mandell, D. J., & Ward, S. E. (2011). Building the blocks of executive functioning: Differentiating early developing processes contributing to executive functioning skills. *Developmental Psychobiology, 53*(8), 796-805.

Mann, K., Guenther, A., Stetter, F., & Ackermann, K. (1999). Rapid recovery from cognitive deficits in abstinent alcoholics: A controlled test-retest study. *Alcohol and Alcoholism, 34*(4), 567-574.

Manning, V. V., Wanigaratne, S. S., Best, D. D., Hill, R. G., Reed, L. J., Ball, D. D., & ... Strang, J. J. (2008). Changes in neuropsychological functioning during alcohol detoxification. *European Addiction Research, 14*(4), 226-233. doi:10.1159/000156479

Mäntylä, T., Rönnlund, M., & Kliegel, M. (2010). Components of executive functioning in metamemory. *Applied Neuropsychology, 17*(4), 289-298. doi:10.1080/09084282.2010.525090

Mayer, W. R. (2012). *Proposed DSM-5 personality traits and substance use: A multi-faceted study.* (Unpublished doctoral dissertation). Louisiana Tech University, Ruston, LA.

Mayes, S., Calhoun, S., & Crowell, E. (2001). Clinical validity and interpretation of the Gordon Diagnostic System in ADHD assessments. *Child Neuropsychology, 7*(1), 32-41. doi:10.1076/chin.7.1.32.3151

Medina, K., Hanson, K. L., Schweinsburg, A. D., Cohen-Zion, M., Nagel, B. J., & Tapert, S. F. (2007). Neuropsychological functioning in adolescent marijuana users: Subtle deficits detectable after a month of abstinence. *Journal of the International Neuropsychological Society, 13*(5), 807-820. doi:10.1017/S1355617707071032

Medina, K. L., Shear, P. K., Schafer, J., Armstrong, T. G., & Dyer, P. (2004). Cognitive functioning and length of abstinence in polysubstance dependent men. *Archives of Clinical Neuropsychology, 19,* 245-258. doi:10.1016/S0887-6177(03)00043-X

Miller, W. R., Tonigan, J. S., & Longabaugh, R. (1995). The Drinker Inventory of Consequences (DrInC): An instrument for assessing adverse consequences of alcohol abuse. *NIAAA Project MATCH Monograph Series, Vol. 4, NIH Publication No. 95-3911.* National Institute on Alcohol Abuse and Alcoholism.

Mintzer, M., Copersino, M., & Stitzer, M. (2005). Opioid abuse and cognitive performance. *Drug and Alcohol Dependence, 78*(2), 225-230.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100.

Morrison, F. (2011). Neuropsychological impairment and relapse following inpatient detoxification in severe alcohol dependence. *International Journal of Mental Health and Addiction, 9*(2), 151-161. doi:10.1007/s11469-009-9261-x

Murdock, K. W., Oddi, K. B., & Bridgett, D. J. (2013). Cognitive correlates of personality: Links between executive functioning and the big five personality traits. *Journal of Individual Differences, 34*(2), 97-104. doi:10.1027/1614-0001/a000104

National Institute on Drug Abuse. (2012). Principles of drug addiction treatment: A research-based guide. *NIH Publication No. 12–4180.* National Institutes of Health.

Nigg, J. T., Wong, M. M., Martel, M. M., Jester, J. M., Puttler, L. I., Glass, J. M., & ... Zucker, R. A. (2006). Poor response inhibition as a predictor of problem drinking and illicit drug use in adolescents at risk for alcoholism and other substance use disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 45*(4), 468-475. doi:10.1097/01.chi.0000199028.76452.a9

O'Brien, J. W., Norman, A. L., Fryer, S. L., Tapert, S. F., Paulus, M. P., Jones, K. L., & ... Mattson, S. N. (2013). Effect of predictive cuing on response inhibition in children with heavy prenatal alcohol exposure. *Alcoholism Clinical and Experimental Research, 37*(4), 644-654.

Ornstein, T. J., Iddon, J. L., Baldacchino, A. M., Sahakian, B. J., London, M. M., Everitt, B. J., & Robbins, T. W. (2000). Profiles of cognitive dysfunction in chronic amphetamine and heroin abusers. *Neuropsychopharmacology, 23*(2), 113-126.

Oscar-Berman, M., & Marinkovic, K. (2007). Alcohol: Effects on neurobehavioral functions and the brain. *Neuropsychology Review, 17*(3), 239-257. doi:10.1007/s11065-007-9038-6

Parada, M., Corral, M., Mota, N., Crego, A., Rodríguez Holguín, S., & Cadaveira, F. (2012). Executive functioning and alcohol binge drinking in university students. *Addictive Behaviors, 37*(2), 167-172.

Piechatzek, M., Indlekofer, F., Daamen, M., Glasmacher, C., Lieb, R., Pfister, H., & ... Schutz, C. G. (2009). Is moderate substance use associated with altered executive functioning in a population-based sample of young adults? *Human Psychopharmacology: Clinical and Experimental, 24*(8), 650-665.

Pitel, A., Beaunieux, H., Witkowski, T., Vabret, F., Guillery-Girard, B., Quinette, P., & ... Eustache, F. (2007). Genuine episodic memory deficits and executive dysfunctions in alcoholic subjects early in abstinence. *Alcoholism, Clinical and Experimental Research, 31*(7), 1169-1178.

Prosser, J., London, E., & Galynker, I. (2009). Sustained attention in patients receiving and abstinent following methadone maintenance treatment for opiate dependence: Performance and neuroimaging results. *Drug and Alcohol Dependence, 104*(3), 228-240. doi:10.1016/j.drugalcdep.2009.04.022

Rapeli, P., Kivisaari, R., Autti, T., Kähkönen, S., Puuskari, V., Jokela, O., & Kalska, H. (2006). Cognitive function during early abstinence from opioid dependence: A comparison to age, gender, and verbal intelligence matched controls. *BMC Psychiatry, 6*(9). doi:10.1186/1471-244X-6-9

Reynolds, C. R. (2002). *Comprehensive Trail Making Test: Examiner's manual.* Austin, TX: PRO-ED.

Rinn, W., Desai, N., Rosenblatt, H., & Gastfriend, D. R. (2002). Addiction denial and cognitive dysfunction: A preliminary investigation. *The Journal of Neuropsychiatry and Clinical Neurosciences, 14*(1), 52-57. doi:10.1176/appi.neuropsych.14.1.52

Ross, T., Furr, A., Carter, S., & Weinberg, M. (2006). The psychometric equivalence of two alternate forms of the Controlled Oral Word Association Test. *The Clinical Neuropsychologist, 20*(3), 414-431.

Rosselli, M., Ardila, A., Lubomski, M., Murray, S., & King, K. (2001). Personality profile and neuropsychological test performance in chronic cocaine-abusers. *International Journal of Neuroscience, 110*(1), 55-72. doi:10.3109/00207450108994221

Santor, D., Ingram, A., & Kusumakar, V. (2003). Influence of executive functioning difficulties on verbal aggression in adolescents: Moderating effects of winning and losing and increasing and decreasing levels of provocation. *Aggressive Behavior, 29*, 475–488.

Sanzen Neuropsychological Assessment Tests (2012). *Tower of London Manual.* Colorado Springs, CO: Sanzen.

Sarter, M., Givens, B., & Bruno, J. P. (2001). The cognitive neuroscience of sustained attention: Where top–down meets bottom–up. *Brain Research Reviews, 35*(2), 146-160. doi:10.1016/S0165-0173(01)00044-3

Schnirman, G. M., Welsh, M. C., & Retzlaff, P. D. (1998). Development of the Tower of London—Revised. *Assessment, 5*(4), 355-360. doi:10.1177/107319119800500404

Schretlen, D. J., van der Hulst, E., Pearlson, G. D., & Gordon, B. (2010). A neuropsychological study of personality: Trait openness in relation to intelligence, fluency, and executive functioning. *Journal of Clinical and Experimental Neuropsychology, 32*(10), 1068-1073. doi:10.1080/13803391003689770

Schwartz, R. H., Gruenewald, P. J., Klitzner, M., & Fedio, P. (1989). Short-term memory impairment in cannabis-dependent adolescents. *American Journal of Diseases of Children, 143*(10), 1214-1219.

Sclafani, V., Tolou-Shams, M., Price, L. J., & Fein, G. (2002). Neuropsychological performance of individuals dependent on crack-cocaine, or crack-cocaine and alcohol, at 6 weeks and 6 months of abstinence. *Drug and Alcohol Dependence, 66*(2), 161-171.

Severtson, S., Mitchell, M., Mancha, B., & Latimer, W. (2009). The association between planning abilities and sharing injection drug use equipment among injection drug users in Baltimore, MD. *Journal of Substance Use, 14*(5), 325-333. doi:10.3109/14659890802668763

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London Biological Sciences, 298*(1089), 199-210.

Simon, S. L., Domier, C., Carnell, J., Brethen, P., Rawson, R., & Ling, W. (2000). Cognitive impairment in individuals currently using methamphetamine. *American Journal on Addictions, 9*(3), 222-231.

Smith, S., Servesco, A., Edwards, J., Rahban, R., Barazani, S., Nowinski, L., & ... Green, J. (2008). Exploring the validity of the Comprehensive Trail Making Test. *The Clinical Neuropsychologist, 22*(3), 507-518.

Snyder, H. R. (2013). Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: A meta-analysis and review. *Psychological Bulletin, 139*(1), 81-132.

Sofuoglu, M., Waters, A. J., Poling, J., & Carroll, K. M. (2011). Galantamine improves sustained attention in chronic cocaine users. *Experimental and Clinical Psychopharmacology, 19*(1), 11-19.

Sprague, J., Verona , E., Kalkhoff, W., & Kilmer, A. (2011). Moderators and mediators of the stress-aggression relationship: Executive function and state anger. *Emotion 11*, 61–73.

Stanford, M., Greve, K., & Gerstle, J. (1997). Neuropsychological correlates of self-reported impulsive aggression in a college sample. *Personality and Individual Differences 23*, 961–965.

Stevens, M. C., Kaplan, R. F., & Bauer, L. O. (2001). Relationship of cognitive ability to the developmental course of antisocial behavior in substance-dependent patients. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 25,* 1523-1536. doi:10.1016/S0278-5846(01)00210-X

Streeter, C. C., Terhune, D. B., Whitfield, T. H., Gruber, S., Sarid-Segal, O., Silveri, M. M., & ... Yurgelun-Todd, D. A. (2008). Performance on the Stroop predicts treatment compliance in cocaine-dependent individuals. *Neuropsychopharmacology*, *33*(4), 827-836. doi:10.1038/sj.npp.1301465

Stuss, D. T., & Alexander, M. P. (2000). Executive functions and the frontal lobes: A conceptual view. *Psychological Research*, *63*(3), 289.

Substance Abuse and Mental Health Services Administration. (2012). Results from the 2011 National Survey on Drug Use and Health: Summary of national findings. *HHS Publication No. 12-4713*. Substance Abuse and Mental Health Services Administration.

Sumerall, S. W., & Timmons, P. L. (1997). Expanded norms for the Controlled Oral Word Association Test. *Journal of Clinical Psychology*, *53*(5), 517-521.

Swick, D., Ashley, V., Turken, U. (2011). Are the neural correlates of stopping and not going identical? Quantitative meta-analysis of two response inhibition tasks. *NeuroImage, 56,* 1655–1665.

Takagi, M., Yücel, M., Cotton, S. M., Baliz, Y., Tucker, A., Elkins, K., & Lubman, D. I. (2011). Verbal memory, learning, and executive functioning among adolescent inhalant and cannabis users. *Journal of Studies on Alcohol and Drugs*, *72*(1), 96-105.

Tarter, R. E., Kirisci, L., Mezzich, A., Cornelius, J. R., Pajer, K., Vanyukov, M., & ... Clark, D. (2003). Neurobehavioral disinhibition in childhood predicts early age at onset of substance use disorder. *The American Journal of Psychiatry*, *160*(6), 1078-1085. doi:10.1176/appi.ajp.160.6.1078

Terracciano, A., Lockhenhoff, C., Crum, R., Bienvenu, O., & Costa, P. (2008). Five-factor model personality profiles of drug users. *BMC Psychiatry*, *8*, 1-10. doi:10.1186/1471-244X-8-22

Tracy, J., & Young, T. (2012). *The relationship between cognitive ability and motivation in substance abuse treatment.* (Unpublished doctoral dissertation). Louisiana Tech University, Ruston, LA.

Trenerry, M. R., Crosson, B., DeBoe, J., & Leber, W. R. (1989). *Stroop Neuropsychological Screening Test*. Odessa, FL: Psychological Assessment Resources.

Trull, T., Jahng, S., Tomko, R., Wood, P., & Sher, K. (2010). Revised NESARC personality disorder diagnoses: Gender, prevalence, and comorbidity with substance dependence disorders. *Journal of Personality Disorders, 24*(4), 412-426. doi:10.1521/pedi.2010.24.4.41

Turner, T. H., LaRowe, S., Horner, M., Herron, J., & Malcolm, R. (2009). Measures of cognitive functioning as predictors of treatment outcome for cocaine dependence. *Journal of Substance Abuse Treatment*, *37*(4), 328-334. doi:10.1016/j.jsat.2009.03.009

United States Department of Education National Center for Education Statistics. (2015). The condition of education 2015. Educational Attainment, NCES, 2015–144. Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=27

Unterrainer, J. M., Rahm, B. B., Kaller, C. P., Leonhart, R. R., Quiske, K. K., Hoppe-Seyler, K. K., & ... Halsband, U. U. (2004). Planning abilities and the Tower of London: Is this task measuring a discrete cognitive function? *Journal of Clinical and Experimental Neuropsychology*, *26*(6), 846-856.

Van der Elst, W., Van Boxtel, M., Van Breukelen, G., & Jolles, J. (2006). The Stroop Color-Word Test: Influence of age, sex, and education; and normative data for a large sample across the adult age range. *Assessment*, *13*(1), 62-79.

Verdejo-García, A., Betanzos-Espinosa, P., Lozano, O., Vergara-Moragues, E., González-Saiz, F., Fernández-Calderón, F., & ... Pérez-García, M. (2012). Self-regulation and treatment retention in cocaine dependent individuals: A longitudinal study. *Drug and Alcohol Dependence*, *122*(1-2), 142-148.

Verdejo-García, A., Lopez-Torrecillas, F., Gimenez, C., & Pérez-García, M. (2004). Clinical implications and methodological challenges in the study of the neuropsychological correlates of cannabis, stimulant, and opioid abuse. *Neuropsychology Review*, *14*(1), 1-41.

Verdejo-García, A., & Pérez-García, M. (2007). Profile of executive deficits in cocaine and heroin polysubstance users: Common and differential effects on separate executive components. *Psychopharmacology*, *190*(4), 517-530. doi:10.1007/s00213-006-0632-8

Verdejo-García, A., Sánchez-Fernández, M., Alonso-Maroto, L., Fernández-Calderón, F., Perales, J. C., Lozano, Ó., & Pérez-García, M. (2010). Impulsivity and executive functions in polysubstance-using rave attenders. *Psychopharmacology*, *210*(3), 377-392. doi:10.1007/s00213-010-1833-8

Walling, S., Meehan, J., Marshall, A., Holtzworth-Munroe, A., & Taft, C. (2012). The relationship of intimate partner aggression to head injury, executive functioning, and intelligence. *Journal of Marital and Family Therapy*, *38*(3), 471-485. doi:10.1111/j.1752-0606.2011.00226.x

Ward, G., & Allport, A. (1997). Planning and problem solving using the five-disc Tower of London task. *The Quarterly Journal of Experimental Psychology, 50A*, 49-78.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (2008). *Wechsler Adult Intelligence Test – Fourth Edition (WAIS-IV)*. Texas: Pearson.

Weiss, R. D., Griffin, M. L., & Mirin, S. M. (1992). Drug abuse as self-medication for depression: An empirical study. *The American Journal of Drug and Alcohol Abuse*, *18*(2), 121-129. doi:10.3109/00952999208992825

Wilmsmeier, A., Ohrmann, P., Suslow, T., Siegmund, A., Koelkebeck, K., Rothermundt, M., &... Pedersen, A. (2010). Neural correlates of set-shifting: Decomposing executive functions in schizophrenia. *Journal of Psychiatry and Neuroscience*, *35*(5), 321-329.

Wittchen, H., Froehlich, C., Behrendt, S., Guenther, A., Rehm, J., Zimmermann, P., & ... Perkonigg, A. (2007). Cannabis use and cannabis use disorders and their relationship to mental disorders: A 10-year prospective-longitudinal community study in adolescents. *Drug and Alcohol Dependence*, *88*(1), 60-70.

Yu, A. J. (2011). Uncertainty and neuromodulation: Acetylcholine and sustained attention. In O. Vartanian & D. R. Mandel (Eds.), *Neuroscience of Decision Making* (pp. 97-123). New York: Psychology Press.

Zinn, S., Stein, R., & Swartzwelder, H. (2004). Executive functioning early in abstinence from alcohol. *Alcoholism Clinical and Experimental Research*, *28*(9), 1338-1346.

Zook, N. A., Davalos, D. B., DeLosh, E. L., & Davis, H. P. (2004). Working memory, inhibition, and fluid intelligence as predictors of performance on Tower of Hanoi and London Tasks. *Brain and Cognition*, *56*(3), 286-292.