ABSTRACT

Verbal and Working Memory Deficits in an Impulsive Aggressive College Sample

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Impulsive aggressors often report difficulties remembering details of their aggressive outbursts. Additionally, researchers have found impairments in working and verbal memory and in executive functions in both impulsive and aggressive populations. However, previous studies have not distinguished between aggressive subtypes when studying memory. A major goal of this research was to extend previous studies and employ both neuropsychological assessment and event-related potentials (ERPs) to investigate memory impairment, especially verbal and working memory impairment, in a well defined, impulsive aggressive population.

Participants were 58 college students comprised of two groups: impulsive aggressors and non-aggressive controls. The control group scored higher on several measures of verbal memory: Long Delay Free Recall (CVLT-II), Vocabulary (WASI), Logical Memory – 1st recall total and thematic total and Family Pictures I and II (WMS-III). These indicate both short- and long-term verbal memory differences.

Additionally, we found that controls were more accurate on all measures of working memory: Letter-Number Sequencing and Spatial Span (WMS-III), *n*-back,

Sequential Spatial Memory Task (SMT). Only the Sequential SMT reached statistical significance. However, a trend was seen such that as working memory load increased, the difference between group scores also increased.

A significant group x stimulus (match/ no- match) interaction was found for P300 amplitude, with controls exhibiting larger P300 amplitudes for low probability match stimuli compared to high probability no-match stimuli during a high-load working memory task (3-back). This difference was not seen in impulsive aggressors, indicating impulsive aggressors process information differently than non-aggressive controls.

Finally, as working memory load increases during an ERP task, it is expected that P300 amplitude at the Pz electrode will decrease continuously while the amplitude at Fz increases continuously. This was true of the controls. In the impulsive aggressive group, however, the continuous decrease in Pz amplitude was seen, but the continuous increase in Fz amplitude discontinued completely once they appeared to reach a working memory overload, dropping to a baseline level. Although memory deficits in this impulsive aggressive college sample are not blatantly obvious, when pushed to their cognitive limits, differences in information processing as well as in both verbal and working memory become apparent.

Verbal And Working Memory Deficits In An Impulsive Aggressive College Sample

by

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A Dissertation

Approved by the Department of Psychology and Neuroscience

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LIST OF ABBREVIATIONS

ADD	Attention Deficit Disorder
ADHD	Attention Deficit Hyperactivity Disorder
AD-HKD	Attention Deficit/ Hyperkinetic Disorder
ANOVA	Analysis of Variance
APD	Antisocial Personality Disorder
AUDIT	Alcohol Use Disorders Identification Test
BIS - 11	Barratt Impulsiveness Scale
Cont.	Non-aggressive Control
CPT	Continuous Performance Task
CVLT – II	California Verbal Learning Test
DAST - 20	Drug Abuse Screening Test
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision
EDS	Episodic Dyscontrol Syndrome
EEG	Electroencephalogram
ERP	Event-Related Potential
FP	Family Pictures
GORT	Gray Oral Reading Test
IA-QS	Impulsive Aggression Quick Screen
IA	Impulsive Aggressor
IED	Intermittent Explosive Disorder

IQ	Intelligence Quotient
LHAQ	Lifetime History of Aggression Questionnaire
LM	Logical Memory
M	Mean
MMPI	Minnesota Multiphasic Personality Inventory
μV	Microvolt
ms	Milliseconds
Recog.	Recognition
SD	Standard Deviation
SMT	The Spatial Memory Task
WASI	Wechsler Abbreviated Scale of Intelligence
WISC	Wechsler Intelligence Scale for Children
WMS	Wechsler Memory Scale
WRAT	Wide Range Achievement Test

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DEDICATION

To Ryan … my heart, my soul, my everything

CHAPTER ONE

Introduction

One of the greatest problems facing society today is violence. Although violent crime rates have been decreasing over the past decade, it is estimated that 4 to 6 million violent crimes occur each year in the United States with over 5 million having been reported for 2003, representing 22.3% of all crime (Bureau of Justice Statistics, 2003). Approximately 29% of homicides in the United States are impulsive in nature (National Institute of Justice, 1993). Individuals who display impulsive aggressive behavior put themselves, their families, and society as a whole at risk while also placing a significant strain on criminal justice, public health, and psychiatric services (Stanford, Greve, & Gerstle, 1997). Dealing with the effects of such violence is costing millions if not billions of dollars to society (Gregg & Siegel, 2001; Miczek, Fish, de Bold, & de Almeida, 2002).

In an extensive review of the impulsivity and aggression literature Hollander and Stein (1995) concluded that the "remaining problems in the field of impulsivity and aggression include…the need for better definition and both dimensional and categorical variables" (p. 4). Over the past several years, researchers have identified factors predisposing individuals to impulsive aggression as well as provided a more descriptive aggression classification system. Additionally, a major goal of researchers has been to discover differences in aggressive individuals including behavioral, neurological, and physiological deviations. Finally, a significant focus has been placed on the development of preventative and/or treatment strategies (Kellam, Mayer, Rebok, & Hawkins, 1998;

Vance, Fernandez, & Baber, 1998; Villemarette-Pittman, Stanford, & Greve, 2003). By understanding the neurobiological causes of impulsive aggression, preventative strategies and effective treatments may advance further.

Aggressive Subtypes

Although there is no universally accepted nosology of aggression, researchers generally agree that aggression can be differentiated as either premeditated or impulsive. Aggression, like other characteristics, seems to be normally distributed such that at extremes there are individuals that are entirely premeditated aggressors or entirely impulsive aggressors. The majority of aggressors, however, are some combination of the two forms, usually with one predominant form (Stanford, Mathias, Houston, & Villemarette-Pittman, 2001). Meloy (2006) therefore characterized the distinction as dimensional rather than categorical, and further pointed out the importance of determining the mode of violence in assessing the risk of future violence as well as the anticipated efficacy of prospective treatment.

Individuals that are predominately premeditated aggressors, also referred to as controlled, predatory, proactive, or instrumental aggressors (Barratt, Stanford, Dowdy, Liebman, & Kent, 1999; Miczek, et al., 2002; Stanford et al., 2001b; Stanford et al., 2005), have been characterized as displaying planned, conscious, goal-directed, aggressive acts. These acts are not spontaneous or related to an agitated state; they are committed in a controlled, unemotional manner (Meloy, 2006; Stanford et al., 2003). These intentional acts are instrumental in nature (Stanford et al., 2005), are often related to social gain or dominance (Barratt et al., 1999), and are carried out with low autonomic arousal (Houston, Stanford, Villemarette-Pittman, Conklin, & Helfritz, 2003; Meloy, 2006). In contrast to impulsive aggressors, premeditated aggressors show a lack of emotional awareness (Houston et al., 2003). Additionally, premeditated aggressors exhibit more severe physical violence. In general, premeditated aggressive acts are more likely to be termed "cold-blooded" (Barratt et al., 1999).

In contrast, aggressive outbursts committed by those who are predominately impulsive aggressors, also known as affective, reactive, emotional, expressive, hot-blooded, defensive, or hostile aggressors (McEllistrem, 2004; Meloy, 2006; Miczek et al., 2002; Stanford et al., 2005), are immediate and spontaneous responses to provocation without concern for consequences. These responses are also accompanied by a loss of behavioral control (Stanford et al., 2003). These aggressive acts are preceded by high levels of autonomic arousal and are characterized by anger and/or fear (Meloy, 2006). The goal of an impulsive aggressive act is to reduce threat (whatever the provocation – internal or external) and return to biological homeostasis (McEllistrem, 2004). Barratt (1991, p. S37) described an impulsive aggressive outburst as "a hair trigger response to a stimulus that results in an agitated state and culminates in an aggressive act; during the agitated state, interpersonal communication is nonadaptive and information processing appears to be inefficient." In addition, upon reflection impulsive aggressors feel their aggressive response was inappropriate for the situation and they feel remorse and contend that they will never do it again, though they often do (Barratt et al., 1999). They frequently make poor decisions in problem solving situations (Villemarette-Pittman et al., 2003). Impulsive aggressors also experience thought confusion and dramatic mood changes following an aggressive outburst (Barratt et al., 1999).

A great deal of aggression research has been conducted using animal models. In the cat, the typical "impulsive aggressive" act is characterized by arched back, piloerection, display of teeth and claws, pupil dilations, vocalization, and ears tilted backward, and generally occurs in response to a threat (Meloy, 2006). Similar behavior has been identified in mice, rats, dogs, and primates. This behavior developed evolutionally for self-preservation. In contrast, the "premeditated aggression" of a cat can be seen in the quiet movements as it inches towards a wounded bird, ears tilted forward, not displaying any teeth or claws until the attack occurs. There is no sympathetic arousal or pupil dilation. The evolutionary basis for this behavior is the goal-oriented behavior of hunting for food (Meloy, 2006).

One can see, then, that premeditated and impulsive aggressors differ in personality, behavioral control, emotionality, and evolutionary basis. Additional differences exist in psychopathology, electrophysiology, neurophysiology, neuropsychology, neurochemistry, treatment efficacy, and predictive measures. As impulsive aggression is the focus of this study, the following is a review of the characteristics underlying this aggression subtype.

Aggression and Personality

The three personality traits most often associated with aggression are anger/hostility, irritability, and, impulsivity. Irritability refers to an explosive, uncontrolled type of hostility (Stanford, Greve, & Dickens, 1995). Coccaro, Harvey, Kupsaw-Lawrence, Herbert, & Bernstein (1991) hypothesized that irritability is the behavioral trait that leads to an aggressive state in response to provocation. Also, Stanford et al. (1995) found irritability to be so highly correlated with the number of impulsive aggressive outbursts that it may be used to help in identifying potentially violent people.

Impulsivity, a predisposition toward unplanned reactions to stimuli without regard to consequences (Dougherty et al., 2003), has been associated with increased risk-taking behavior, poor school performance, increased behavior problems, and younger age at time of first arrest (Villemarette-Pittman et al., 2003). Houston and Stanford (2005) compared three groups – impulsive aggressors, impulsive non-aggressors, and controls. Impulsive aggressors, those reporting more acts of verbal and/or physical aggression, also reported more feelings of anger and hostility than either of the other two groups, illustrating that impulsivity alone does not provoke aggression. Barratt (1991) proposed that impulsive aggression "involves a balance between the levels of impulsiveness or impulsive control and anger-hostility" (S37). Barratt, Stanford, Felthous, and Kent (1997) proposed that anger and hostility are the motivation for aggression while impulsivity mediates the expression of anger.

As anger/hostility, irritability, and impulsivity are generally found in aggressive populations, finding these characteristics is not helpful in subtyping. However, there are other personality traits that are unique to impulsive aggression. Impulsive aggressors are unable to deal with stress and are often suicidal and self-mutilative (Hubbard et al., 2002). Also, impulsive aggressors are very fearful of the negative criticism of others (Hubbard et al., 2002). Additionally, impulsive aggressors are prone to boredom (Dahlen, Martin, Ragan, & Kuhlman, 2004). They see their behavioral control problem as aversive and are more likely to seek help than premeditated aggressors (Stanford et al., 2001b). In a study of impulsive aggressive college students using the Psychopathic

Personality Inventory, Helfritz and Stanford (2006) found that compared to controls, impulsive aggressors were high in Machiavellian Egocentricity, Blame Externalization, Impulsive Nonconformity, and Carefree Nonplanfulness, indicating that they "frequently lose control of their behavior, are unusually susceptible to the negative effects of life stressors, and are not particularly effective in social situations" (p. 35). Additionally, they were low in Coldheartedness and Stress Immunity as compared to controls. This implies that impulsive aggressors are overly emotional (or more sensitive) as well as more anxious than are their non-impulsive aggressive counterparts.

Aggression and Psychopathology

Aggression is associated with a variety of psychopathology, the most common of which are antisocial and borderline personality disorders (Stanford et al., 2005). These disorders are linked to both premeditated and impulsive aggression (Barratt et al., 1997b). In fact, in their study of impulsive and premeditated prison inmates, Barratt et al. (1997b) diagnosed every inmate in the study with antisocial personality disorder. Because these personality disorders are so prevalent in both aggressive subtypes, diagnosis of such is not useful in classification.

In contrast, there are differences in psychopathology between these two aggressive forms that can be used to distinguish between them. Impulsive aggressors display more severe psychopathology. Stanford et al. (2005) assessed a community sample of male impulsive aggressors for DSM-IV-TR Axis I and Axis II personality disorders and found that of their 29 participants, 12 were diagnosed with at least one Axis I disorder (major depression $n = 5$, alcohol abuse $n = 7$, and substance abuse $n = 4$). In addition, 24 participants were diagnosed with an Axis II personality disorder (antisocial n

= 17, borderline n = 3, obsessive-compulsive n = 2; narcissistic n = 1, and paranoid n = 1). Seven of the 29 were comorbid for Axis I and Axis II diagnoses. Similarly, in a study of domestic batterers, Tweed and Dutton (1998) found increased diagnoses of passive-aggressive, borderline, and avoidant personality disorders on the Millon Clinical Multiaxial Inventory scales. In addition, Villemarette-Pittman, Stanford, Greve, Houston, & Mathias (2004) found an increased rate of obsessive-compulsive personality disorder in impulsive aggressors. Impulsive aggression has also been associated with attention deficit hyperactivity disorder and bipolar disorder (American Psychiatric Association, 2000). Helfritz and Stanford (2006) found impulsive aggressive college students score higher on almost every clinical measure of the Personality Assessment Inventory than non-aggressive controls, including schizophrenia, anxiety, anxiety-related disorders, depression, mania, somatic complaints, borderline, alcohol problems, and substance problems. These studies indicated a global elevation in psychopathology among impulsive aggressors.

Episodic Dyscontrol Syndrome (EDS) and Intermittent Explosive Disorder (IED) are characterized by behavior patterns similar to those of impulsive aggression (Houston et al., 2003). EDS is essentially the same as impulsive aggression. It is a term used by some researchers to describe violence as a result of poor impulse control usually as a response to fear, anger, or rage (McEllistrem, 2004). IED is the title given to this behavior by the *Diagnostic and Statistical Manual of Mental Disorders* (APA, 2000). IED populations show increased frequency of Axis II disorders, especially antisocial personality disorder (Galovski, Blanchard, &Veazey, 2002), as well as Axis I disorders such as bipolar disorder, depression, anxiety disorders, substance abuse, and other impulse-control disorders, leading authors to conclude that IED is truly an impulse control disorder (McElroy, Soutullo, Beckman, Taylor, & Keck, 1998). Monroe hypothesized that IED results from an inefficient "urge control mechanism" that is either overwhelmed by an extreme drive or underdeveloped and overwhelmed by a normal urge (McEllistrem, 2004).

Aggression and Electrophysiology

Impulsive aggressors have a variety of neurological deficits (Stanford et al., 2005). These deficits affect the individual's ability to process and react to environmental stimuli. Among these deficits are problems with physiological arousal which lead to sensation seeking and impulsive behaviors as well as impaired executive function, verbal deficits, increased attentional orienting and processing, increased arousability, and greater physiological reactivity (Barratt et al., 1997a; Barratt et al., 1997b; Houston & Stanford, 2001; Stanford et al., 2001a).

Many of these deficits result in impulsive aggressors' constant search for optimal arousal levels (Houston & Stanford, 2001). Impulsive aggressors are generally under-aroused (Barratt et al., 1997a). For example, in a study of prison inmates and non-inmate controls, Barratt et al. (1997b) found that during an odd-ball task, non-impulsive aggressive inmates (premeditated aggressors) and non-inmate controls were more aroused to new task demands than were the impulsive aggressive inmates. These same authors (Barratt et al, 1997a) hypothesized that impulsive aggressors use fewer neural resources during visual information processing compared to premeditated aggressors and controls. Further, impulsive aggressors display decreased arousal during resting conditions (Barratt et al., 1997b; Houston & Stanford, 2005; Stanford et al., 2001a). "It has been suggested that sudden surges in arousal induce an agitated state that the impulsive-aggressive individual is unable to control" (Stanford et al., 2001a, p. 194).

Additionally, abnormalities of electrocortical function are found in impulsive aggressive individuals. Event related potentials (ERPs) (recorded during electroencephalograms [EEGs]) are believed to measure brain functioning related to information processing (Mathias & Stanford, 1999). One component of the ERP, the P300, is a positive peak that occurs approximately 300 ms after a stimulus is presented (Barratt et al., 1997a). The P300 is thought to reflect memory updating, transfer of information to consciousness, and information processing (Kim, Kim, & Kwon, 2001). P300 latency is a measure of stimulus evaluation time while lower P300 amplitude indicates fewer neural resources available for information processing or less efficient cognitive processing (Gerstle, Mathias, & Stanford, 1998; Mathias & Stanford, 1999). Cognitive processes thought to be associated with P300 amplitude include attention, stimulus probability, arousal, memory context upgrading, and reducing uncertainty (Barratt et al., 1997b). Additionally, P300 amplitude is determined by the subjective probability of the stimulus rather than its prior probability (Barratt et al., 1997b).

An association between P300 amplitude and pathological states has also been noted (Barratt et al., 1997b) Reduced P300 amplitudes have been found in substance abusers' children with behavioral problems, and antisocial-personality disordered individuals (Stanford, Conklin, Helfritz, & Kockler, 2004). Impulsive aggressive individuals display both increased P300 latency (Mathias & Stanford, 1999) as well as reduced P300 amplitudes (Barratt et al., 1997b; Gerstle et al., 1998; Mathias & Stanford, 1999).

Other ERP abnormalities have also been found in impulsive aggressors. These include increased P1-N1 amplitude, decreased P1 amplitude, increased N1 amplitude, and shortened P1-N1-P2 latency (Houston & Stanford, 2001; Stanford et al., 2001a). However, the significance of this will be discussed later.

Aggression and Neurophysiology

Numerous areas of brain dysfunction have been identified in impulsive aggressive individuals, including the prefrontal cortex, as well as temporal lobe and parieto-occipital lobe dysfunction (Barratt et al., 1997; Dolan, Deakin, Roberts, & Anderson, 2002; Kim, 2002; Krynicki, 1978; Raine et al., 2001; Seguin, Nagin, Assaad, & Tremblay, 2004). For example, decreased glucose uptake in the prefrontal cortex is common to impulsive aggressive individuals (Soloff, Meltzer, Greer, Constantine, & Kelly, 2000). A more in-depth review of research indicating this dysfunction will follow later in the discussion of memory.

Aggression and Neuropsychology

Executive function. Several researchers have identified neuropsychological dysfunction in aggressive individuals (Barratt et al., 1997b; Spellacy, 1977). However, few authors relate these deficiencies specifically to impulsive aggression. Executive cognitive functioning is involved in the regulation of goal-directed behaviors including attentional control, concentration, strategic goal planning, learning of contingency rules, concept formation, hypothesis generation, organization, social/self-monitoring, inhibitory control, motor behavior skills, set shifting in response to changing environmental demands, anticipation of events, temporal ordering, associative learning, problem solving, abstract flexibility, and cognitive flexibility (Fuster, 1997; Giancola & Tarter, 1999; Moffitt & Henry, 1989; Seguin, Pihl, Harden, Tremblay, & Boulerice, 1995). Together these functions allow the implementation of behavior appropriate for a given situation (Ishikawa, Raine, Lencz, Bihrle, & Lacasse, 2001). These abilities operate within working memory and require active monitoring (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Seguin et al., 1995). The working memory processes are, in turn, dependent upon basic (or general) memory processes (Seguin et al., 1995).

Executive function is largely, but not exclusively, controlled by the dorsolateral prefrontal cortex (Cornoldi, Barbieri, Gaiani, & Zocchi, 2000; Ishikawa et al., 2001; Seguin et al., 2004), which, as previously mentioned, is impaired in impulsive aggressors. In a study of college students divided into impulsive aggressive and non-aggressive controls, Stanford et al. (1997) found that impulsive aggressive individuals performed poorly on tests of executive function (Wisconsin Card Sorting Task and Trails B) when compared to controls as a result of an increased number of impulsive errors as well as attentional errors. Similarly, Dolan et al., (2002) found impulsivity and aggression to be correlated with poor executive function and that aggression is inversely related to memory function.

Because executive functioning encompasses the ability to interpret body language, the social meaning of facial expression, and the rhythmic aspects of oral communication (Giancola, 1995; Moffitt, 1990), deficits in executive function may result in misinterpretations of threat or hostility in conflict situations. This may undermine further the ability to generate alternative socially adaptive behavioral responses and to execute a sequence of responses necessary to avoid aggressive or stressful situations

(Giancola, 1995). Thus, the tendency for impulsive aggressive individuals to overreact to threat or perceived threat may be a result of impaired executive function.

Verbal ability. In addition to executive dysfunction, language deficits have also been particularly apparent in both impulsive and aggressive populations, including low scores in vocabulary, language and reading comprehension, receptive and expressive language, sentence repetition and completion, and verbal intelligence and memory (Harmon-Jones, Barratt, & Wigg, 1997; Lewis, Shanok, Balla, & Bard, 1980; Richman & Lindgren, 1981; Spellacy, 1977; Stanford & Barratt, 1996). Verbal abilities have been assessed in impulsive and aggressive populations in all age groups. For example, Richman and Lindgren (1981) assessed 59 children (aged seven to eleven years) at a pediatric psychology outpatient clinic who were referred for behavioral problems, learning difficulties, somatic complaints, or emotional problems. After being administered several verbal assessments from the Wechsler Intelligence Scale for Children (WISC), Hiskey-Nebraska Test of Learning Aptitude, and Wide Range Achievement Test (WRAT), they divided the children into three groups as having mostly sequencing-memory problems, mostly abstract reasoning problems, or those having general learning problems and then compared them on scores on the Behavior Problem Checklist. They found that the group with mostly abstract reasoning problems had a higher level of inhibition and lower level of acting out than either of the two groups. The group with mainly sequencing-memory problems appeared to make some use of verbal mediation as evidenced by their higher level of inhibition, although they still only scored moderately on acting-out. Additionally, they were unable to attain the reading levels of the abstract reasoning group, even though their Verbal IQ was the same. The group with general language problems scored poorly on both inhibition and acting out, evidencing only minimal verbal mediation. They also scored lower on reading and math assessments and had lower Verbal IQs. These authors suggest that different cognitive processes underlie the different patterns of behavior, and thus understanding what the impaired processes are provides direction in helping children function in the classroom environment.

Stanford and Barratt (1996) assessed 155 high-school aged males and found that impulsivity and verbal intelligence were inversely related (as assessed by the WISC-revised [WISC-R], WRAT, and Gray Oral Reading Test [GORT]) and pointed out that this is consistent with other studies which have found relationships between verbal intelligence and antisocial behavior in juveniles. Additionally, in their study of 34 adolescents at a psychiatric in-patient unit, Harmon-Jones et al., (1997) found that reading level negatively correlated with attentional and non-planning impulsiveness as well as physical and verbal aggression.

In a study of college-aged students, Stanford et al. (1997) compared 12 impulsive aggressors to 12 non-aggressive controls. The impulsive aggressors were impaired in verbal strategic processing as evidenced by their performance on the Controlled Oral Word Association Test.

Mungas (1988) found both language and visual-perceptual deficits in impulsive, frequently violent outpatients. When comparing impulsive aggressive inmates to non-impulsive aggressive inmates and non-inmate controls, Barratt et al. (1997b) found the impulsive aggressive groups scored lower on all measures of verbal skills(including the similarities and vocabulary subtests from the WAIS , the projected Verbal IQ, Verbal

Memory from the WMS-R, and the GORT). Upon further analysis, they concluded that the differences between the groups were a result of a particular verbal information processing deficit, developmental dyslexia. Also, Dolan and Anderson (2002) showed that impulsivity and aggression both negatively correlate with verbal intelligence. These authors hypothesized that the deficit in verbal skills may contribute to impulsive behavior because of these individual's inability to use internal verbal controls to mediate and inhibit behaviors. Another hypothesis cited by them is that the analytical brain processes of these individuals fail to develop as quickly as the impulsive, irrational behaviors mediated by the motor areas. As a result, their behavior becomes impulsive, aggressive, and antisocial. Of course, it is also possible that these individuals rely on aggression because they do not have the verbal skills to handle a negative social environment.

Despite all this evidence pointing to a relationship between impulsivity, aggression, and verbal skills, other researchers have provided counter-arguments. For example, Seguin et al. (1995) studied verbal learning, spatial learning, tactile-lateral ability, and executive function in physically aggressive boys (six to twelve years old) and found that only executive function highly correlated with aggression. They pointed out, however, that tests of executive function require working memory, which in turn has the prerequisites of verbal and spatial learning. Also, Villemarette-Pittman et al. (2003) reported that verbal deficits in impulsive aggressive college students varied according to the extent of the demands placed on executive function. Thus, the authors concluded that the poorer scores of impulsive aggressive individuals were a result of impaired executive function, and not purely poor verbal skills.

Lewis et al. (1980) conducted an interesting study assessing reading disability in a group of 59 incarcerated boys (aged 12 to 18) at a correctional school. They compared them on violence measures and various neuropsychological measures, and found that poor readers were more violent than better readers and that poor readers had working memory problems (as assessed by a Digit Span Backwards task). They suggested that the reason for both these findings is delayed cognitive development in the poor readers. They went on to say that:

> it is tempting to consider the possibility that in some instances the very behaviors of these delinquent children resulting in incarceration were reflections of an immaturity effecting poor impulse control, the ability to appreciate the point of view of the recipient of an aggressive act, and the ability to envision the long-term consequences of an act….If a child cannot organize his thoughts, remember the immediate past, or put himself in another's place, it would seem almost impossible for him to imagine or appreciate the consequences of his actions (p. 620).

Memory. Impulsive aggressive individuals also display impaired memories (Dolan et al., 2002). While general memory (those functions associated with the hippocampus and medial temporal lobes including short-term and long-term memory) is distinct from executive function, impairments in general memory will necessarily affect executive function (Seguin et al., 2004). A review of the research demonstrating general memory dysfunction in impulsive aggressors will come later.

Beyond deficits in executive function, language abilities, and memory, additional deficits of impulsive aggressors are seen in fine and gross motor skills (Lewis et al., 1980; Stanford & Barratt, 1996) as well as in perceptual organization (Mungas, 1988).

Aggression and Neurochemistry

Aggressive individuals have abnormal levels of several neurotransmitters compared to healthy controls including serotonin, gamma aminobutyric acid (GABA), norepinephrine, dopamine, and acetylcholine. Generally, serotonergic and GABAergic systems appear to inhibit impulsive aggression while noradrenergic and dopaminergic systems facilitate impulsive aggression (McEllistrem, 2004; Meloy, 2006).

Aggression and Treatment Efficacy

Treatment with anticonvulsants, including Dilantin, Tegretol, and Depakote (aka phenytoin, carbamazepine, and valproate), have proven beneficial in impulsive aggressive populations (Barratt et al., 1997a). Anticonvulsants effectively reduce the number of aggressive outbursts and normalize the P300 ERP, as well as other ERP abnormalities, in impulsive aggressive individuals, but not in premeditated aggressors (Barratt et al., 1997b; Stanford et al., 2001a). For example, phenytoin prolonged P1-N1 latencies and reduced N1 amplitude in impulsive aggressors (Stanford et al., 2001a). Also, phenytoin significantly reduced the frequency and intensity of violent outbursts in impulsive aggressors (Barratt et al., 1991; 1997a; Stanford et al., 2001a). Beta-blockers and selective serotonin reuptake inhibitors are also effective in treating impulsive aggression (Meloy, 2006).

The difference in treatment efficacy is important when trying to reduce the problem of aggression. Because impulsive but not premeditated aggressors respond favorably to anticonvulsants distinguishing between aggressive subtypes is critically important.

Aggression and Predictive Measures

Being able to distinguish between aggressive subtypes facilitates being able to predict future outcomes. For example, in children and adolescents proactive, but not reactive aggression, predicts later delinquency and disruptive behavior (Houston et al., 2003, Spellacy, 1977). Also, murderers whose violence was classified as impulsive are more likely to fail on parole than those whose murders were premeditated in nature (Houston et al., 2003; Stanford et al., 2003).

Clearly there are two forms of primary aggression that, while they have similarities, have distinct personality, biological, physiological, and cognitive correlates. Being able to distinguish between these subtypes has tremendous clinical, legal, and policy implications. Although a better understanding of the cognitive processing deficits that underlie aggression will aid in identification of individuals at risk of committing aggressive acts and in development of effective treatments/interventions to control or prevent future violence, few studies have attempted to determine the neurocognitive substrates that may underlie this problem behavior (Stanford et al., 2004**).**

Spellacy (1977) argued that neuropsychological test may be a better way to discriminate between violent and nonviolent boys than self-report personality measures because self-report measures:

> make the assumption that behavioral traits that are associated with impulse dyscontrol and are liable to lead to violence are amenable to self-report. Many adolescents appear to be vulnerable to periodic outbursts wherein violence is only a manifestation of a general pattern of poorly controlled behavior, which ordinarily would not be considered aspects of personality. To the extent that brain dysfunction is present in violence-prone groups, one may expect the assessment of simple perceptual and cognitive abilities may facilitate significantly the detection of subjects prone to violent behavior (p. 966).

He administered the Minnesota Multiphasic Personality Inventory (MMPI), subtests from the WISC, and a series of tests chosen from the University of Victoria Neuropsychology Laboratory selected for their sensitivity to temporal lobe dysfunction to 40 violent and 40 nonviolent delinquent adolescent boys (12-17) at a treatment school. The nonviolent group scored significantly better on 25 of the 31 neuropsychological variables. In contrast, there were no significant differences found on the MMPI. Using a stepwise discriminate analysis, the 31 neuropsychological variables correctly classified 86.3% of the subjects while the 10 clinical scales and 3 validity scales of the MMPI classified only 71%. Spellacy concludes that neuropsychological evaluations add significant information to the assessment of delinquent adolescents and that they may be used to predict future aggressive antisocial behavior. Therefore, it is important that more research be done to better understand exactly what neuropsychological deficiencies are present in impulsive aggressors so that identification and intervention can occur earlier.

Memory and Impulsive Aggression

Cognition in Impulsive Aggressors

Many researchers have found evidence indicating impulsive aggressive individuals have cognitive deficiencies. According to Janowsky, Kraus, Barnhill, Elamir, and Davis (2003), intellectual disability is often associated with aggressive behavior, including aggression towards self and others, even violent behavior towards objects. The following review relates cognitive impairment to the impulsive aggressive population.

Areas of Brain Dysfunction Found in Impulsive Aggressors

Several areas of the brain have been identified as being dysfunctional in impulsive aggressive individuals. The most commonly cited area of dysfunction in impulsive aggressors is the frontal lobe, specifically the dorsolateral frontal cortex as well as the orbitofrontal cortex and ventromedial prefrontal cortex (Barratt et al., 1997b; Bechara, Damasio, & Damasio, 2000; Birnbaum et al., 2004; Dolan & Anderson, 2002; Eslinger, Biddle, Penningtion, & Page, 1999; Giancola, Mezzich, & Tarter, 1998; Kim, 2002; Krynicki, 1978; Raine et al., 2001; Seguin et al., 2004). Decreased glucose uptake in the prefrontal cortex is common to impulsive aggressive individuals (Soloff, et al., 2000) and according to Birnbaum et al. (2004), impulsivity is a sign of prefrontal cortex dysfunction (see also, Berlin, Rolls, & Kischka, 2004).

For example, when a 7-year-old boy received a dorsolateral prefrontal cortex lesion he developed a short attention span as well as impulsive responses (Eslinger et al., 1999). Decreased metabolism in the orbitofrontal cortex as well as in associated limbic pathways, including the amygdala and the hippocampus, are found in impulsive aggressors (Kim, 2002; see also Bechara et al., 2000; Raine et al., 2001). Impaired metabolism in the orbitofrontal cortex has been associated with increased aggression in individuals with personality disorders as well as with healthy subjects imagining aggressive behavior (Kim, 2002). In addition, Bechera, Damasio, and Damasio (2000) found that patients with an injured ventromedial prefrontal cortex do not consider the future consequences of their actions.

> The prefrontal cortex is the primary neocortical site for representation of information processed by the limbic system. The orbital-medial areas receive input from limbic structures in the cingulate and anterior temporal lobes. Integrity of the underlying corticolimbic circuitry is a primary factor in emotional

> and behavioral regulation. Lesions to the orbital-medial area … are associated with profound dysregulation of affect and impulse (including disinhibited, socially inappropriate behaviors, impulsive aggression, sensation seeking, irritability, and emotional liability, and devastating personality changes), while leaving intact other cognitive performance functions (Soloff, et al., 2000, p. 545).

Similarly, Barratt, Bryant, Felthous, and Kent (1990) said that injured frontal lobes (especially the orbital region) lead to "lack of foresight, inability to plan and judge consequences of actions, and lack of concern for difficulties encountered" (p. 141-142). As a result these individuals may become antisocial or criminal. Also, as mentioned previously, executive function is largely under the control of the frontal lobes. Additionally, the left dorsolateral frontal cortex is involved in word retrieval (Seguin et al., 1995). This helps explain why executive function and verbal deficiencies are often found in impulsive aggressors.

The temporal lobe is another region implicated in impulsive aggression (Barratt et al., 1997b; Krynicki, 1978; Raine et al., 2001). Raine et al. (2001) found reduced metabolism in medial temporal regions in impulsive aggressors. Additionally, Barratt et al. (1990) found that when both temporal lobes are damaged as well as the right frontal lobe, violence resulted as well as hypersexuality, hyperorality, and fluctuating emotions. The temporal cortices have been implicated in word storage (Seguin et al., 1995) further explaining impulsive aggressors poor verbal skills.

In addition, deficient parieto-occipital lobes (Barratt et al., 1997b) as well as deficits in subcortical and white-matter areas (Raine et al., 2001) are found in impulsive aggressive individuals. Damaged limbic structures have also been implicated in aggressive behavior including the hypothalamus, hippocampus, and amygdala (McEllistrem, 2004), which may explain not only some of their cognitive defects (memory difficulties) but also their proneness towards aggression since the limbic system is involved in mood regulation. As mentioned previously, impaired neurotransmitter function is also found in impulsive aggressive populations.

Hemispheric differences in aggressive and impulsive behaviors remains controversial (Raine et al., 2001). For example, Dolan and Anderson (2002) found that impulsive aggressive individuals have deficits on several dorsolateral prefrontal markers, but especially those which impact concept formation in a verbal format which requires left hemisphere resources. Similarly, according to Seguin et al. (1995) the link between poor verbal skills and aggressive behavior suggests there is left hemisphere damage. On the other hand, Raine et al. (2001) found that violent adults that were severely abused as children have reduced right hemisphere (especially right temporal cortex) functioning compared to non-violent adults that had been severely abused (who had good right hemisphere function with poor left hemisphere functioning.) Apparently more research is needed to clarify which, if either, hemisphere is responsible for impulsive aggression.

Barratt et al. (1997a) summed up the relationship between impulsive aggressors, cognitive impairment, and areas of brain dysfunction.

> Frontal lobe dysfunctioning and high levels of trait impulsiveness and anger may be necessary but are not sufficient for the development of impulsive aggression. Developmental dyslexia and related brain dysfunction in the parieto-occipital and temporal areas (especially in the left hemisphere) in addition to frontal lobe dysfunctioning seem necessary for the development of impulsive aggression. One possible general explanation of the cortical bases for impulsive aggression involves poor temporal information processing and varying and lowered thresholds for cortical arousability. It has been shown that impulsiveness (a frontal lobe process) and verbal skills (especially reading) help define a second-order factor of temporal information processing (p. 347).

Psychophysiological Differences in Impulsive Aggressors

Impulsive aggressors and non-aggressive controls display various psychophysiological differences. For example, impulsive aggressors have increased P1-N1 amplitudes in response to increasing stimulus intensity, decreased P1 amplitudes, increased N1 amplitudes, and shortened P1-N1-P2 latency (Stanford et al., 2001a).

Increased P1-N1 amplitude reflects increased augmenting which supports the idea of greater physiological reactivity. It is hypothesized that the decreased P1 amplitude indicates decreased sensory gating which is further reflected in the heightened physiological reactivity characterizing impulsive aggressors. This may cause the deficient cognitive processing seen in impulsive aggressive individuals during event-related potential paradigms (Stanford et al., 2001a).

The N1 amplitude indicates orienting or attention. Larger N1 amplitude is indicative of the impulsive aggressor's constant search for stimulation in an effort to boost arousal to a more optimal level.

Shorter P1-N1-P2 latency may also reflect the impulsive aggressor's constant search to increase arousal. Also, impulsive aggressors have low levels of arousal during resting conditions which leads to reduced efficiency of executive function (Houston & Stanford, 2001; Stanford et al., 2001a). All of these psychophysiological results provide further evidence of arousal modulation deficits underlying impulsive-aggressive behavior. Thus, impulsive aggressors are unable to normally allocate attention and are under-aroused, so they do not process information normally. This may lead to memory deficiencies.

Working Memory in Impulsive Aggressors

Working memory allows us to hold and manipulate information temporarily (Aronen, Vuontela, Steenari, Slami, & Calrson, 2005; Cohen et al., 1997; D'Esposito et al., 1995; Osaka, Osaka, Kondo, Maoishita, Fukuyama, Shibasaki, 2004; Rypma, Berger, & D'Esposito, 2002). It also is responsible for integrating this information into long-term memory and is fundamental for behaviors such as learning, reasoning, language comprehension, and reading (Aronen et al., 2005). Also, working memory allows us to "shift perspectives on a problem, define goals while considering several parameters of a problem, plan a strategy while anticipating consequences, execute steps of a plan held in memory, monitor progress, detect and correct errors, and accommodate new data while filtering out interference" (Seguin et al., 2004, p. 604). Working memory, therefore, underlies many higher cognitive processes (Cohen et al., 1997; D'Esposito et al., 1995; Osaka et al., 2004; Rypma et al., 2002).

Brain regions involved. Working memory involves a network which links regions of the prefrontal cortex with posterior association cortices (Gevins & Smith, 2000). The prefrontal cortex regulates thought, behavior and emotion using working memory (Birnbaum et al., 2004). Specifically, the dorsolateral prefrontal cortex, among other areas, is linked to working memory (Bechara et al., 2000; Cohen et al., 1997; D'Esposito et al., 1995; Eslinger et al., 1999; Rypma et al., 2002; Seguin, Boulerice, Harden, Tremblay & Pihl, 1999; Stevens, Burkhardt, Hautzinger, Schwartz, & Unkel, 2004). Rypma et al., (2002) identified the dorsolateral prefrontal cortex as being recruited when processing beyond just information maintenance is necessary. It maintains both spatial and auditory working memory (Stevens et al., 2004). Damage to the right dorsolateral frontal cortex in a seven-year-old boy produced impaired executive functioning including attention control, visuospatial working memory, cognitive flexibility, and organization strategies for learning (Eslinger et al., 1999).

In addition, the ventrolateral prefrontal cortex (Rypma et al., 2002), the orbitofrontal prefrontal cortex (Cohen et al., 1997), anterior cingulate cortex (D'Esposito et al., 1995; Osaka et al., 2004), left inferior frontal gyrus, (Cohen et al., 1997; Osaka et al., 2004), and posterior parietal cortex (Cohen et al., 1997) have all been found to be involved in working memory. As discussed previously, these are areas, along with the dorsolateral prefrontal cortex, that are dysfunctional in impulsive aggressive individuals.

Relationship between impulsive aggression and working memory deficits. Gevins and Smith (2000) suggested that since effective working memory is critical to higher cognitive functions, differences in general cognitive ability may be related to observable differences in working memory and attention control. Impulsive and aggressive individuals have been shown to have deficient working memories as well as impaired executive function (Dellu-Hagedorn & Simon; 2004; Finn, Justus, Mazas, & Steinmetz, 1999; Hinson, Jameson, & Whitney, 2003; Stevens et al., 2004; Whitney, Jameson, & Hinson, 2004). For example, Aronen et al. (2005) found that children with teacher reported attentional/behavioral difficulties made more mistakes on working memory tasks than children with no such difficulties.

In their study, Whitney et al. (2004), found that different subtypes of impulsivity are related to different aspects of executive function. For example, individuals who scored high on attentional impulsiveness did poorly on tasks of working memory, as they have difficulty removing irrelevant information from working memory. Furthermore, increased demands on working memory led to an impulsive decision making style (Hinson et al., 2003). Although most studies on impulsive aggression and its relationship to cognitive functioning have been done with males, the relationship between poor executive function and working memory and impulsivity and aggression has also been documented in females (Giancola et al., 1998) and animals (Dellu-Hagdorn & Simon, 2004).

Predictive factors. Seguin et al. (2004) point out that executive function in general and working memory in particular are poor in individuals with a history of physical aggression. Also, children with conduct disorders usually have impaired executive function. Moffitt, Lynam, and Silva (1994) called this relationship the neuropsychological hypothesis and stated their idea thusly: "neuropsychological data support inferences that observable behavior is linked to the physical health of the brain" (p. 278). For example, a history of physical aggression can predict poor working memory in adolescence (Seguin, Arsenault, Boulerice, Harden, & Tremblay, 2002; see also Seguin et al., 1999). Impulsivity in youth can also predict cognitive impairment, including working memory deficiencies, in adulthood (Dellu-Hagedorn & Simon, 2004).

Additionally, Giancola, Moss, Martin, Kirisci, and Tarter (1996) showed that poor working memory in aggressive children at risk for substance abuse can be used to predict future impulsive aggression. Similarly, Moffitt et al. (1994) initially administered a neuropsychological battery (including visuospatial and verbal memory assessments) to several hundred 13-year-olds. Five years later, within 60 days of the eighteenth birthday these individuals were reassessed for delinquent behavior. Boys that had the poorest scores on the neuropsychological evaluations (especially verbal skills and verbal memory) at age 13 were the most delinquent at age 18. Early cognitive deficits (especially executive dysfunction) along with brain-environment interactions led aggressors to a decreased ability to reflect in order to solve interpersonal and social problems when they were in situations requiring adaptive social responses (Seguin et al., 1995). This may lead to impulsivity which may consequently lead to aggression. As a result Seguin et al. (1995) concluded that boys who are consistently violent and have executive dysfunction are at a particularly high risk for a "persistent pattern of antisocial behavior" (p. 622).

General Memory in Impulsive Aggression

As noted earlier, deficits in memory forms beyond working memory are observed. General memory is associated with functions in the hippocampus, dorsomedial thalamic nuclei, mammilary bodies, language cortex, and temporal lobes (Burgess, 1992; Seguin et al., 1995), another indication general memory is distinct from executive function. One interesting finding is that individuals who display impulsive aggressive behavior often have difficulty remembering the details surrounding and corresponding to their outbursts (Barratt et al., 1997b).

Seguin et al. (1995) compared consistently aggressive boys (not distinguished by aggressive form), non-consistently aggressive boys, and non-aggressive boys on measures of working memory, verbal skills and memory, spatial memory, and tactile laterality. The tests of verbal and spatial memory were specifically chosen because they did not tap on working memory or the brain regions involved in it. However, the skills assessed in these tasks are "prerequisites" for working memory and executive functions. On the other hand, the verbal learning tests did not rely heavily on active executive function skills. The consistently aggressive boys performed more poorly on all measures except tactile laterality than either of the other two groups. These impairments may be undetectable neuroanatomically, such that poor performance does not necessarily imply a brain lesion or neurodevelopmental delay, but instead may result from neurochemical or physiological impairment.

Agrawal & Kaushal (1987) compared auditory short-term memory in normal children, aggressive children, and non-aggressive children with attention deficit disorder (ADD). Both aggressive children and children with ADD performed poorer than controls. Similarly, Krynicki (1978) found that behaviorally disordered/assaultive boys performed poorer on a verbal short-term memory task than did nonassaultive behaviorally disordered adolescents. Interestingly, the violent adolescents performed similarly to brain damaged adolescents on these verbal tasks. Also, in a study comparing personality disordered offenders and non-aggressive healthy controls, Dolan and Anderson (2002) found that those high in impulsivity and aggression had significantly lower scores on the Logical Memory subtests from WMS-R than did controls. Additionally, impulsive individuals display trouble sustaining and manipulating objects in short-term memory (Dickman, 1993).

Memory Impairment in Similar Populations

Although the research regarding general memory function in impulsive aggressive individuals is sparse, only a few have distinguished aggressive subtypes, some research has been done assessing memory in similar populations. Included in these populations are individuals with attention deficit hyperactivity disorder (ADHD), conduct disorder, borderline personality disorder, and antisocial personality disorder.

Attention Deficit Hyperactivity Disorder. ADHD, occurring in 3% of children, is characterized by activity, inattention, and extreme impulsiveness (Johnson, Altamaier, & Richman, 2000). Children with ADHD frequently have low self-esteem and emotional instability. These individuals also tend to have impaired academic performance (Johnson et al., 2000). Studies done assessing memory in this population indicate impairment in several areas of memory, including both short- and long-term memory (Dige & Wik, 2005; Hervey, Epstein, & Curry, 2004; Johnson et al., 2000; West, Houghton, Douglas, & Whiting, 2002), verbal and visual memory (Dige & Wik, 2005; Dowson et al., 2004; Hervey et al., 2004; Kaplan, Dewey, Crawford, & Fisher, 1998; Lufi & Cohen, 1985; Rhodes, Coghill, & Matthews, 2004; West et al., 2002), effortful memory (Aloisi, McKone, & Heubeck, 2004; Ott & Lyman, 1993), explicit memory (Aloisi et al., 2004), working memory (Shallice et al. 2002), and strategic memory (Cornoldi et al., 2000).

For example, in their study of 31 ADHD children (compared with 33 normal controls) Shallice et al. (2002) found that the ADHD children did significantly more poorly on a numeral *n*-back test of working memory. West et al. (2002) compared boys with ADHD (with no diagnosed comorbid conditions) with age-matched controls. The ADHD boys performed poorer on tests of immediate and delayed verbal and non-verbal memory as measured by the Children's Memory Scale. Similarly, Kaplan et al. (1998) administered tasks from the Wide Range Assessment of Memory and Learning that distinguished between inattentiveness and memory and found that ADHD children performed poorly on subtests assessing attention/concentration as well as on general, verbal, and visual memory. However, they did not find a difference in performance on tasks sensitive to long-term memory. They conclude that ADHD caused impaired initial learning due to inattention, but did not affect long-term retention of learned information (as measured by the Wide Range Assessment of Memory and Learning). Further, Rhodes et al. (2004) compared boys with attention deficit/ hyperkinetic disorder (AD-HKD) with healthy boys on performance on spatial working memory, simultaneous and delayed matching-to-sample, and pattern recognition tests and found the AD-HKD boys performed poorer on all measures.

Most studies assessing characteristics and limitations of ADHD utilize children. Adults who have ADHD often display memory impairment as well. For example, Dige and Wik (2005) compared an adult ADHD group to a control groups on several measures of memory, executive functions, and other skills and found impaired verbal short- and long-term memory and visual short- and long-term memory, as well as impaired performance on other tasks. Hervey et al. (2004) also reported impaired working memory as well as verbal short- and long-term memory but not visuospatial memory in adult ADHD. On the other hand Dowson et al. (2004) found ADHD adults to be particularly impaired in spatial working memory. From this example we can see that some results have been conflicting, which is also the case in the child ADHD literature (ie. Geurts et al., 2004).

Despite these discrepancies, it is apparent that some memory impairment can be found throughout this population, while other forms of memory appear to be unaffected. For example, ADHD children perform poorer on tasks of free-recall than normal children but had similar spatial memories (Ott & Lyman, 19993). The authors hypothesized this indicated impaired effortful memory but not automatic memory in children with ADHD. Similarly, when comparing ADHD children with matched controls on measures of implicit and explicit memory, Aloisi et al., (2004) found the ADHD group performed poorer on tasks of explicit memory for pictures, but not on implicit memory tasks. They too theorized this indicates ADHD kids have impaired effortful memory but intact automatic processes.

Conduct disorder. Conduct disorder is the most frequently diagnosed psychiatric disorder in children and adolescents, affecting between 6 and 16% of males under the age of 18 (Dolan & Park, 2002). Conduct Disorder is characterized by destruction of property, running away from home, truancy, deceitfulness, theft, persistent aggression, and other serious rule violations (Kim et al., 2001). Studies comparing conduct disordered youth with age matched normal controls indicate memory impairment in those with conduct disorder. For example, Lueger & Gill (1990) found conduct disordered adolescents performed more poorly on measures of low load working memory, motor memory, and verbal recall memory, tasks that are all sensitive to frontal lobe functioning. Likewise Olvera, Semrud-Clikeman, Pliszka, & O'Donnell (2005) found that adolescents with conduct disorder showed impaired performance on measures of verbal memory and visuo-spatial memory. In contrast, Kim et al. (2001) found conduct disordered adolescents were not different on measures of spatial or recognition memory than age-matched controls.

Borderline personality disorder. Borderline personality disorder is a psychological disorder characterized by maladaptive personality, emotional turmoil, suicidality, instability of mood and interpersonal relationships, and impulsivity. The disorder is found in about 1% of adults (Paris, 2005). These individuals have also been found to have impaired memories. In a sample of 37 patients with dramatic personalities, largely made up of borderline individuals (whether solely borderline or comorbid with histrionic, narcissitic, or antisocial) but also including histrionic, narcissistic, and antisocial, Burgess (1992) found significantly impaired delayed memory when compared to matched normal controls. However, he did not find any significant difference in immediate memory span. Swirsky-Sacchetti et al. (1993) administered several tests of memory which assess verbal memory, figural memory, and logical memory (both immediate and delayed) to borderline and control groups and found the control group performed better on all measures, though the difference was only significant for figural (visual) memory (both immediate and delayed). Also, Dowson et al. (2004) found adults with borderline personality disorder to have impaired spatial working memory. Stevens et al. (2004) found similar results. In an interesting study assessing autobiographical memory using the Autobiographical Memory Test in depressed and non-depressed borderline patients as well as depressed patients and controls, Kremers, Spoinhoven, & Van der Does, (2004) found that depressed borderline patients and depressed patients had impaired autobiographical memories. Although it appears individuals with borderline personality have impaired memories, when Sprock, Rader, Kendall, & Yoder (2000) administered several memory assessments to controls and borderline patients including figural, logical, digit span, and verbal memory they found that there was no significant difference in performance on any test, though controls generally performed slightly better.

Antisocial personality disorder. Another personality disorder, antisocial personality disorder (APD), found in about 1% of females and 3% of males (Roth & Finley, 1998), is characterized by persistently behaving without regard for the safety, rights, or feelings of others and without regard for the consequences of their actions. Though few studies have assessed the memories of these individuals Dolan & Park (2002) compared controls with an APD group and found the APD subjects were impaired in visual memory as measured by the simultaneous matching to sample task in the Cambridge Neuropsychological Test Automated Battery.

Memory exists in many different forms and stages. Several forms of memory have just been addressed. However, up to this point there has been no discussion on the stages of memory. An understanding of both forms and stages is important to the understanding of memory as a whole, which is in turn important in understanding the impact of particular forms of memory impairment.

A Memory Model

Lezak (1995) describes a three-stage model of declarative memory which begins with sensory memory, followed by short-term memory (of which rehearsal and consolidation are part), and finally long-term memory (including retrieval). Lezak's memory model is very similar to Atkinson and Shiffrin's modal model of memory developed in the late 1960's (Baddeley, 1990). Since that time many multi-level memory models have been proposed, largely with the three main components of sensory memory, short-term memory, and long-term memory.

According to Lezak (1995) sensory memory, also called registration, holds large amounts of information for brief periods of time in a "sensory store". Through sensory memory perceptions are selected and stored in the memory system. There are two main forms of sensory memory which Neisser has termed iconic memory and echoic memory (Baddeley, 1990). Iconic memory is visual sensory memory and can hold approximately 9 pieces of information for about 200 msec. Echoic memory, on the other hand, is auditory sensory memory and has a capacity of around 5 or 6 items which lasts for around 2000 msec. (Baddeley, 1990; Lezak, 1995). In either sensory memory system, if the information taken in is not registered, if attention is not focused on it, it will quickly decay. However, if this information is registered it will enter the short-term memory system (Lezak, 1995).

Short-term memory, also called immediate or primary memory, is the stage of memory where information is temporarily held, with a duration of approximately 30 seconds and a capacity of about seven pieces of information (Lezak, 1995). Short-term memory is highly-dependent on attention. If distraction interferes the information in short-term memory may rapidly be lost. In short-term memory there is an integration of pertinent sensory memories. It also makes it possible for us to respond to ongoing events. In brief, primary short-term memory is a limited capacity store for information before it is transferred to a more permanent store, long-term memory.

A specific form of short-term memory is working memory by which we are able to hold information in our minds, internalize this information, and then use it to guide our behavior (Lezak, 1995). Like sensory memory, working memory has different systems for the different senses. Baddeley (1990) has called these subsystems the phonological loop, which processes language, and the visuospatial sketchpad, which processes visuospatial data. In addition to these sensory systems there is a "central executive" which is an attentional control center (Aronen et al., 2005) involved in allocating attention to both internally maintained and externally presented information during performance of complex tasks (Whitney et al., 2004). Working memory thus has two major types of components: the storage component specific to the sense (verbal or visual spatial storage) and the processing to executive function component which allows the stored information to be compared, manipulated, coordinated, and selected (Myerson, Emery, White, & Hale, 2003).

Rehearsal is a repetitive memory process serving to lengthen the duration of a memory trace (Lezak, 1995). Rehearsal increases the likelihood that information will be stored permanently, though it does not ensure it. On the other hand, if information is not rehearsed, it is unlikely to be transferred to long-term memory.

Consolidation is the process of storing information in long-term memory and may occur quickly or take a considerable amount of time (Lezak, 1995). Consolidation does not require active involvement; however it is possible to interrupt it by such things as head injury or drug use.

Long-term memory, also called secondary memory, is exactly as the name implies, the storage of memory for a long duration. These memories may endure from hours up to lifetimes. One interesting difference between short-term memory and long-term memory is that information in long-term memory is organized or coded based on meaning whereas in short-term memory information is coded in terms of sensory properties, such as sounds, shapes, and colors (Lezak, 1995). Memory researchers have identified many different forms of long-term memory but one of the major divisions of types of long-term memory is the episodic/ semantic distinction. Episodic memory is the memory for events, or memory of one's own experiences. It is thus unique and can be identified according to location and time. Semantic memory, on the other hand, is the kind of memory that has been learned as knowledge – the kind of memory employed in the school setting. Semantic memory is then the memory for facts such as the alphabet or how to do long division. Thus, it is timeless and spaceless (Lezak, 1995).

In addition to the cognitive operations enabled (long-term, short-term, or working memory) memory can also be defined on the central nervous system (CNS) structures implicated therein. For example, the hippocampus is central to long-term memory while the prefrontal cortex is central to working memory (especially ones sensitive to interference) (Buhot et al., 2003).

The effectiveness of our memories depends on how accessible these memories are. When a memory is called to our attention it is done by way of retrieval. There are two main forms of retrieval – recall and recognition. Recall involves an active, complex search process without the aid of a stimulus (Lezak, 1995). Recognition on the other hand is cued retrieval, remembering occurs by recognition. Retrieval by recognition is much easier than retrieval by recall.

Several memory tests have been developed to assess short- and long-term memory, including working memory, recall, and recognition. Although sensory memory can be tested, and it is from such tests that we know the capacity and duration of such memory forms, it is tested far less frequently than these other stages and/or forms of memory. As mentioned previously, memory is coded differently based on the senses employed and the stage of the memory. Thus, in order to fully assess memory, several different tests are necessary to obtain a wide enogh wide spectrum to cover all forms (visual/auditory, episodic/semantic, recall/recognition, etc.) as well as stages (short- or long-term). Additionally, tests should be selected based on their sensitivity to the CNS structures underlying memory.

Purpose

Previous research suggests that impulsive aggressive individuals may have impaired working memory. Yet there has not been a study fully assessing the memory capabilities of a well defined impulsive aggressive group, nor has there been a study specifically assessing working memory in such a population. It is believed that by designing such a study a better understanding of which aspects of working memory are impaired in this population will arise. Further, other areas of memory may also be identified as deficient. Burgess (1992) believes that neurocognitive testing of individuals with dramatic personalities (such as impulsive aggression) will provide information about their thinking styles and limitations related to behavioral impulsivity which may aid in our understanding of and communication with patients with dramatic personalities.

In light of the vast amount of research implicating cognitive dysfunction in impulsive individuals as well as the evidence of problems in working memory and verbal information processing in conduct disordered individuals, it is proposed that a well defined group of impulsive aggressive individuals will perform poorly on measures of working and verbal memory, and will possibly show poor performance in other areas of memory as compared to non-aggressive controls. A unique feature of the current study is the broad array of memory domains that are covered, including visual and auditory working, short-, and long-term memory through both recognition and recall skills using both neuropsychological and electrophysiological methods. Most previous studies have covered only a subset of these domains. In order to assess all these areas while also placing emphasis on working memory and verbal memory, the Wechsler Memory Scale – Third Edition (WMS-III), the California Verbal Learning Test – Second Edition (CVLT-II), The Spatial Memory Task, and the *n*-back test of spatial memory will be used. To my knowledge the present study is the first study that directly compares college students with well defined impulsive aggression (as to frequency, intensity, and focus of aggressive outbursts) and non-aggressive controls on an extensive battery of memory measures that covers all the major domains of declarative memory.

The current study has six specific aims:

1) To identify a well defined group of impulsive aggressors and to compare them with non-aggressive controls.

2) To identify what areas of working memory are impaired in impulsive aggressors.

3) To identify what areas of verbal memory are impaired in impulsive aggressors.

4) To identify if any other forms of memory are impaired in impulsive aggressors.

5) To identify any differences in P300 amplitude or latency present in impulsive aggressors during working and short-term memory tasks.

6) To identify any areas of brain impairment as can be assessed by event-related potentials.

CHAPTER TWO

Methods and Measures

Subjects

A power analysis indicated 16 subjects would be needed for each group (α=.05, P=.80, average effect size= .51). Twenty nine impulsive aggressive individuals were recruited from the Baylor University subject pool and offered extra credit for participating. In addition to these impulsive aggressive individuals, another set of 29 non-aggressive individuals were also recruited from the Baylor University subject pool and offered extra credit (total n = 58). This second group served as a non-aggressive control group. Subjects were matched as far as was possible on age (18-26 years), gender (20 males, 38 females), year in school (30 freshman, 15 sophomores, 11 juniors, 2 seniors), race (35 Caucasian, 4 African American, 14 Asian, 3 Hispanic, 2 Other), and handedness (51 right, 7 left). Two separate studies were developed in which all the same subjects were used. However, due to computer failures, not all subjects were included in all analyses of Study Two.

Inclusion Criteria

For an individual to be classified as impulsive aggressive, they were required to meet the following criteria: 1) Over the past six months, the participant identified several discrete episodes of failure to resist aggressive impulses that resulted in assaultive acts or destruction of property; 2) The degree of aggressiveness expressed during the episodes was grossly out of proportion to any precipitating psychosocial stressors; 3) At least two impulsive aggressive episodes occurred during the month prior to entry into the study; 4) The participant scores an 8 or higher on the Irritability subscale of the Impulsive Aggression Quick Screen (IA-QS; Stanford et al., 1995). The first two criteria are also the first two diagnostic criteria for Intermittent Explosive Disorder (DSM-IV-TR, APA, 2000), and the fourth criterion has been associated with chronic difficulties in aggression control (Stanford et al., 1995).

Exclusion Criteria

In addition, subjects were excluded from the study if any of the following conditions were met: (a) taking psychoactive medications, (b) non-native English speaker, (c) chronic illness.

Assessments/ Instruments

Screening Measure

Impulsive Aggression Quick Screen (IA-QS; Stanford et al., 1995): The IA-QS is an 11 item questionnaire that assesses the extent of an individual's irritability. Participants were asked these questions and responded T or F as they applied to them. To be classified as impulsive aggressive an individual must score 8 or higher. Individuals scoring 3 or lower qualify as potential non-aggressive controls.

Study One

The first study was comprised of a neuropsychological evaluation as well as battery of self-report measures given to assess impulsivity and aggression. The purpose of this study was to assess the memory and verbal abilities of impulsive aggressors as well as assure that there are differences in impulse control and aggression between them and the control group. The following assessments were used.

Self-report measures. Barratt Impulsiveness Scale (BIS-11; Patton, Stanford & Barratt, 1995): The BIS-11 is a 30 item self-report questionnaire designed to assess general impulsiveness taking into account the multi-factorial nature of the construct. The items are scored on a four point scale (Rarely/Never [1], Occasionally [2], Often [3], Almost Always/Always [4]). The internal consistency of the BIS-11 is high with scores ranging from .79 to .83. The validity of the test is also significant as its factors were consistent with past studies and factor intercorrelations were high (Patton et al., 1995).

Lifetime History of Aggression Questionnaire (LHAQ; Coccaro, Berman & Kavoussi, 1997): The LHAQ is an 11 item questionnaire which assesses three subcomponents of aggression history: aggression, social consequences / antisocial behavior and self-directed aggression. A total score is obtained by summing the subscale scores. The total number of occurrences of each item since the age of 13 are scored as follows; None=0, One Event=1, Two or Three Events=2, Four to Nine Events=3, Ten or More Events=4, More Events than Can Be Counted=5. The internal consistency for the LHAQ was also strong, especially for the total score (.88). Reliability was found to be higher for clinical patients than for non-clinical controls. Additionally, concurrent validity of the LHAQ was also significant as it correlated with both the Buss-Durkee Hostility Inventory and the Overt Aggression Scale – Modified for Out-Patients (Coccaro et al., 1997).

Buss-Perry Aggression Questionnaire (Buss & Perry, 1992): This 29 item questionnaire assesses level of aggression. It is composed of four factors: 1) physical aggression (frequency of acting aggressively), b) verbal aggression (frequency of acting aggressively), c) anger (emotional component of aggression), and d) hostility (cognitive component of aggression). The reliability of the Buss-Perry is significant with considerable internal consistency (alphas ranging from .72 to .89) and adequate test-retest reliability (correlations ranging from .72 to .80). Reasonably high factor intercorrelations also indicate sufficient validity (Buss & Perry, 1992).

Drug Abuse Screening Test (DAST-20; Skinner, 1982): The DAST-20 is a 20 item self-report measure designed to identify drug use related problems in the previous year. The respondent is asked to respond "yes" or "no" to each question and a summary score is derived. Higher scores indicated a greater degree of drug-related problems in the previous year. It was used as a covariate to control for the effects of substance use. The DAST-20 showed high test-retest reliability with an inter-class correlation of .78. The DAST-20 has proven to be a valid measure of discriminating between those with current or life-time substances-abuse disorders and those who have never used drugs. Sensitivity, criterion validity, and convergent validity were all high (Cocco & Carrey, 1998).

Alcohol Use Disorders Identification Test (AUDIT; Babor, de la Fuente, Saunders, & Grant, 1992): The AUDIT is a 10-item screening questionnaire developed to identify persons whose alcohol consumption has become harmful to their health. The AUDIT can be used in a variety of settings where it is important to obtain an accurate and quick estimate of alcohol usage. The three subscales of the AUDIT focus on the amount and frequency of drinking, alcohol dependence, and problems caused by alcohol. Items are scored on a Likert-type scale which varies but essentially ranges from "never" to "daily or almost daily". The AUDIT was used as a covariate to control for the effects of alcohol use. Coefficient scores for the internal consistency of the AUDIT range from .55 to .88 and are significant (Shields, Guttmannova, & Caruso, 2004). The sensitivity of the AUDIT is reasonably good, although McCann, Simpson, Ries, Roy-Byrne (2000) found there to be a fairly high number of false negatives (McCann et al., 2000).

Memory and intelligence measures. Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999): The WASI is an abbreviated instrument used to assess intellectual functioning in children and adults (ages 6 to 89). It was used to predict Full Scale IQ. In addition, it also served as a measure of long-term memory. Again, reliability was high with coefficients for adults ranging from .84 to .98. Additionally, validity was also high by correlation with other ability and achievement measures as well as intercorrelations of subtests (Wechsler, 1999).

Wechsler Memory Scale – Third Edition (WMS-III; Wechsler, 1997): The WMS-III is an instrument used to assess several areas of declarative memory in adults and children. Only the 10 required subtests were administered. From these, scores for the following indices were found: auditory immediate memory, visual immediate memory, immediate memory total, auditory delayed memory, visual delayed memory, auditory recognition memory, general memory, and working memory. The WMS-III has proven to be a reliable memory measure with average reliability coefficients ranging from .74 to .93. Additionally, the WMS-III has high diagnostic validity as well as strong convergent validity demonstrated by its high correlation with other memory measures (Wechsler, 1997).

California Verbal Learning Test – Second Edition (CVLT-II; Delis, Kramer, Kaplan, & Ober, 1987): The CVLT-II assesses verbal memory and learning from both a quantitative and qualitative standpoint. There are 19 indices including: Total Recall List A, List B, List B minus List A Trial 1 (Proactive Interference Effect), Short-Delay Free Recall, Short-Delay Free Recall minus List A Trial 5 (Retroactive Interference Effect), Short-Delay Cued Recall, Long-Delay Free Recall, Long-Delay Cued Recall, Semantic Clustering, Serial Clustering, Percent Primacy Recall, Percent Recency Recall, Learning Slope, Recall Consistency, Perseverative Errors, Free-Recall Intrusion Errors, Cued-Recall Intrusion Errors, Recognition Hits, and False Positives. The CVLT-II has high internal consistency (.94) and high validity (as assessed by its correlation with the CVLT, demographic variables known to account for variability in learning and memory, and verbal intelligence as well as internal consistency measures) (Delis et al., 1987).

Study Two

The second study had a dual purpose of assessing the manipulation of working memory load on accuracy and reaction time and also to record P300s during a working memory task with increasing difficulty. The following measures were used.

Psychophysiology. Psychophysiological recordings were taken between the hours of 12:00 PM and 4:00 PM to control for diurnal variations in scalp patterns. Participants were seated in a comfortable chair in a sound and light attenuated chamber. The scalp and mastoids were prepared by vigorous application of rubbing alcohol followed by a mildly abrasive gel (NuPrep). The participant's head was fitted with a Quick-Cap (Neuroscan) containing 64 electrodes, arranged according to the International 10-20 system with standard and intermediate positions. Electrodes were referenced to an average reference, and four electrooculogram (EOG) electrodes were affixed near the eyes in order to record horizontal and vertical eye movements that may contaminate EEG data. An ocular artifact reduction technique was applied to the data offline in order to remove any eye movement contamination.

EEGs were recorded continuously at a sampling rate of 1,000 samples per second and were amplified by SYNAMPS^2 amplifiers (Neuroscan). Filter bandpass was set at 0.1 Hz to 35 Hz. Impedence for each electrode was maintained at less than 5 kΩ. Epochs beginning 100 milliseconds (ms) prior to stimulus onset and extending to 900 ms post-stimulus were created offline.

P300 peak amplitude and latency were determined from baseline (defined as 100 ms prior to stimulus onset). The P300 component of the ERP was defined as the most positive peak occurring between 250 and 450 ms after stimulus onset. Amplitude was measured as the μV (microvolt) deflection from the baseline to peak, and latency was measured as time in ms from stimulus presentation to peak.

Working memory and attention tasks. n-back (Aronen et al., 2005): The *n*-back is a visuospatial short-term and working memory task given in both high-load (2- and 3-back) and low-load (0-back and 1-back) conditions. It involves the presentation of a light gray square presented randomly in one of eight locations around a central fixation cross (Figure 1).

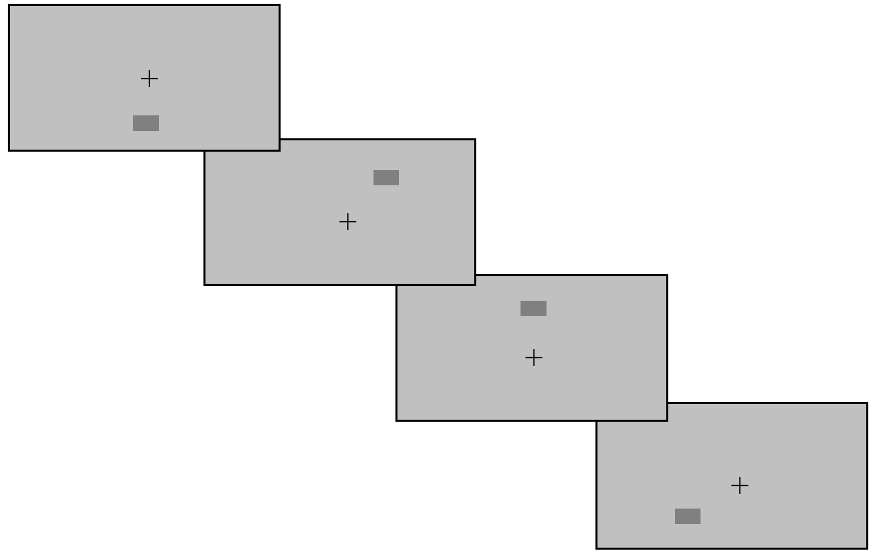


Figure 1. A series of four *n*-back screens.

In the 0-back task, the subject presses the left button of the mouse if the stimulus appeared in a predetermined location or the right button if in any other location. In the 1-back task, the subject presses the left button if the stimulus appears in the same location as the previous stimulus or the right button if in any other location. In the 2-back and 3-back tasks, the subject presses the left button if the stimulus appears in the same location as the one presented two or three trials back (respectively) or the right button if in any other location. During each of the 4 tasks there were 120 trials. Each stimulus was presented for 300 ms with a mean inter-stimulus interval of 4500 ms (range 4000-5000 ms). Order of tasks was randomized for each subject. Originally it was thought to only do up to 2-back, as that is what most *n*-back studies have done. But as there appeared to be a ceiling effect, the 3-back was added after the twelfth subject. The reliability of the *n*-back spatial memory task was also found to be significant with coefficients ranging from .30 to .86. Validity was also high as it significantly correlated with other measures of spatial ability (Hockey & Geffen, 2004).

The Spatial Memory Task (SMT; Neuroscan, 2003): The SMT is a test of short-term (Simultaneous task) and working spatial memory (Sequential task). The test is presented on a computer. Blocks are displayed in cells of 2x2, 3x3, or 4x4 matrices, with increasing difficulty. A number of blocks can be presented simultaneously or they can be presented one at a time (sequentially). The subject is then required to designate the location the objects appeared in as quickly as possible. In the Sequential condition, they also must report their location in the proper order. No prior assessment of the reliability and validity of the SMT was found (Figure 2).

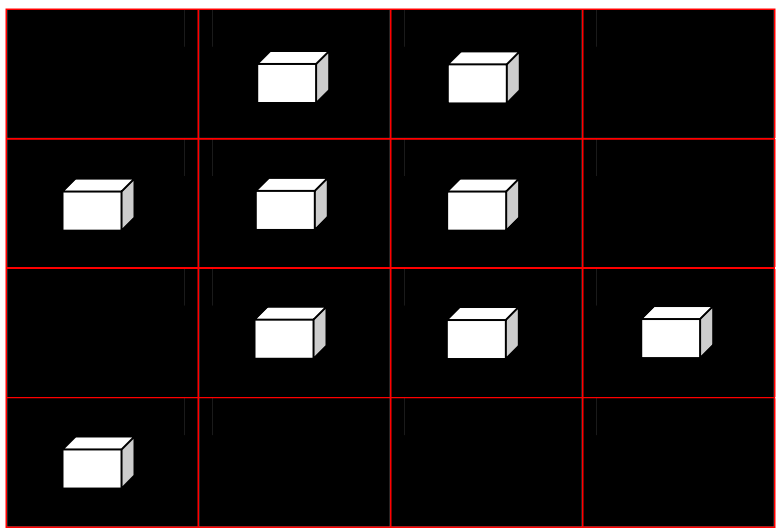


Figure 2. An example of one of the more difficult Simultaneous Spatial Memory Task screens. Sequential tasks would be of similar patterns. While the boxes are being presented no gridlines are shown, they do not appear until it is time for the participant to report the location of the boxes.

Conners' Continual Performance Test (CPT-II; Conners, 2000): The CPT-II is a mainly a measure of attention. It is a computer based task and subjects are instructed to respond by pressing either the space bar or mouse key whenever a frequent non-target letter is flashed, but to suppress response whenever the target "X" is flashed. The computer generates standardized scores for a number of scales, the most frequently considered of which include number of commissions (a measure of impulsivity), number of omissions (a measure of inattention), and reaction time (a measure of either impulsivity or inattention depending on whether it is short or long). The test-retest reliability of the CPT-II ranges from .65 to .74, and the discriminant and concurrent validity are stable (Smith & Corkum, 2007).

Hypotheses

As the areas of the brain involved in working memory have also been found to be impaired in impulsive aggressive populations (Barratt et al., 1997b; Birnbaum et al., 2004; Dolan & Anderson, 2002; Eslinger et al., 1999; Kim, 2002; Krynicki, 1978; Raine et al., 2001; Seguin et al., 2004), working memory has been found to be impaired in similar populations (Dowson et al., 2004; Hervey et al., 2004; Lueger & Gill, 1990), and poor working memory has been associated with both impulsivity and aggression (Dellu-Hagedorn & Simon; 2004; Finn et al., 1999; Hinson et al., 2003; Stevens et al., 2004; Whitney et al., 2004), it was hypothesized that impulsive aggressors would perform more poorly than controls on measures of working memory: Letter-Number Sequencing and Spatial Span from the WMS-III, *n*-back, and Sequential Spatial Memory Task. It was also proposed that the difference between group scores would increase with increasing task difficulty on the *n*-back.

Several studies have identified verbal disabilities in impulsive and aggressive populations, including difficulties with vocabulary and language comprehension (Harmon-Jones et al., 1997; Lewis et al., 1980; Richman & Lindgren, 1981; Spellacy, 1977; Stanford & Barratt, 1996). However, contrary evidence has also been provided

(Seguin et al., 1995; Villemarette-Pittman et al., 2003). It was hypothesized that if there were differences in verbal memory, they would be on the more cognitively demanding verbal memory tasks of the CVLT and WMS-III. Also, impulsive aggressors would score lower on the Vocabulary and Similarities subtests of the WASI.

Impulsive aggressors have been shown to have increased P300 latencies (Mathias & Stanford, 1999) as well as reduced P300 amplitudes (Barratt et al., 1997b; Gerstle et al., 1998; Mathias & Stanford, 1999). Also, greater task demand and lower stimulus probability is associated with increased amplitude (Watter, Geffen, & Geffen, 2001). Additionally, it is common for many P300 tasks, especially for the *n*-back, that as the novelty of the task wears off, the amplitude of the peak decreases (Segalowitz, Wintink, & Cudmore, 2001). This is particularly true at Pz. It is believed this happens because cognitive resources are being reallocated elsewhere. In the *n*-back task, as load increase and the amplitude at Pz decreases, amplitude at Fz has been seen to increase as cognitive resources shift and are reallocated more frontally to perform the higher working memory demands (Segalowitz et al., 2001). Because it is believed that impulsive aggressors have impaired working memories it was hypothesized that the impulsive aggressors would have lower P300 amplitudes and longer P300 latencies than non-aggressive controls during the n-back task. Also, P300 amplitudes of controls would increase at the Fz electrode with increasing working memory load to a greater extent than would the P300 amplitude of impulsive aggressors while the P300 amplitude at Pz decreases. Additionally, it was hypothesized that impulsive aggressors would not have an increased amplitude for match (low probability) relative to non-match (high probability) even at higher task complexity, while the controls would; this has been found to occur in impulsive aggressors during other P300 tasks (Barratt et al., 1997b; Mathias & Stanford, 1999).

Statistical Analysis

Univariate and multivariate analysis of variance (ANOVAs) were used to compare differences between impulsive aggressors and non-aggressive controls on aggression, impulsivity, and memory measures. ERP (P300) amplitude and latency were analyzed using repeated measures ANOVAs. For each ANOVA, group (impulsive aggressive or non-aggressive control) was the between-subjects factor and stimulus match, electrode site, and task load served as within-subjects factors. For analysis of amplitude, the µV deflection from the baseline to the peak served as the dependent variable. In latency analysis, the dependent variable was the average milliseconds from stimulus presentation to the peak. In *n*-back tasks, the maximum peak is seen at the Pz site (Segalowitz et al., 2001; Watter et al.2001). Consequently, analysis focused on the midline electrodes (Fz, Cz, Pz). ANOVA was also conducted to assess between group differences on the behavioral measures (accuracy and reaction time) on the *n*-back task, SMT, and CPT. For all ANOVAs, the Bonferroni inequality was used to control for Type I error rate.

CHAPTER THREE

Results

Study One

Measures of Aggression and Impulsivity

The three major scales of the BIS-11 were analyzed using multivariate ANOVA. Significant differences were found between the two groups on the Attentional Impulsiveness Scale (F[1,56] = 13.05, p = .001. partial η^2 = .189, power = .944) and Non-planning Impulsiveness Scale (F[1,56] = 5.35, p = .024, partial η^2 = .087, power = .623), with the impulsive aggressive group scoring significantly higher than the non-aggressive controls on both. There was not a significant difference between the groups on Motor Impulsiveness Scale. Additionally, univariate ANOVA was used to analyze the BIS-11 total score (F[1,56] = 5.54, p=.022, partial η^2 = .090, power = .638), and found that the impulsive aggressors scored significantly higher (Table 1).

Multivariate ANOVAs were conducted on the three subscales of the LHAQ revealing significant differences for Aggression (F[1,56] = 58.01, p = .000, partial η^2 = .509, power = 1.000), Self-Directed Aggression (F[1,56] = 17.04, p = .000, partial η^2 = .233, power = .982), and Antisocial Behavior (F[1,56] = 37.23, p = .000, partial η^2 = .399, power = 1.000). Additionally, the LHAQ total score was analyzed using univariate ANOVA, differences between groups were also significant: (F[1,56] = 77.43, p = .000, partial η^2 = .580, power = 1.000). The aggressive group scored higher on each scale (Table 1).

Table 1

Self-Report Personality Measures Means and Standard Deviations

	Impulsive Aggressors		Non-Aggressive Controls	
Assessment	*M*	*SD*	*M*	*SD*
Barratt Impulsiveness Scale - 11				
Attentional	21.17***	3.85	18.00	2.75
Motor	23.66	5.81	23.03	6.87
Non-planning	25.34*	5.54	22.28	4.50
Total	70.17*	11.70	63.31	10.47
Lifetime History of Aggression Questionnaire				
Aggression	15.55***	3.67	7.59	4.27
Self-Directed	2.00***	2.00	0.35	0.81
Antisocial	3.62***	2.86	0.31	0.60
Total	21.17***	6.50	8.24	4.51
Buss-Perry Aggression Questionnaire				
Physical	28.07***	7.21	14.86	4.76
Verbal	17.66***	4.27	12.00	3.59
Anger	23.79***	4.65	12.04	3.32
Hostility	27.48***	6.98	15.36	4.67
Total	97.00***	17.95	54.25	11.51

Note. Higher scores indicate greater degree of representative characteristic; * denotes significant differences from controls ($p \leq 0.05$); *** denotes significant differences from controls ($p \leq 0.001$). Impulsive Aggressors ($n = 29$), Non-aggressive Controls ($n = 29$).

The four scales of the Buss-Perry were analyzed using multivariate ANOVA and significant differences were found between the two groups on all four with the aggressive group scoring higher on each: Physical Aggression (F[1,55] = 66.22, p = .000, partial η^2 = .546, power = 1.000), Verbal Aggression (F[1,55] = 29.19, p = .000, partial η^2 = .347, power = 1.000), Anger (F[1,55] = 119.85, p = .000, partial η^2 = .685, power = 1.000), and Hostility (F[1,55] = 59.03, p = .000, partial η^2 = .518, power = 1.000). As would be expected, when the total score was analyzed with univariate ANOVA, the difference between groups was also significant with the impulsive aggressors scoring higher (F[1,55] = 113.65, p = .000, partial η^2 = .674, power = 1.000) (Table 1).

Neuropsychological Measures

The Wechsler Memory Scale – III. The indices, subscales, subtests, and some elements of subtests measured by the computerized scoring system of the WMS-III were analyzed using univariate and multivariate ANOVAs. Only those either specifically referred to in the hypotheses or those found to be significantly different between the two groups will be discussed.

Although controls did score higher than impulsive aggressors on Letter-Number Sequencing (F[1,56] = .028, p = .867, partial η^2 = .001, power = .053), the difference was non-significant. Similarly, although the controls scored higher on Spatial Span (F[1,56] = .481, p = .491, partial η^2 = .009, power = .105), the difference was not significant. However, with increasing working memory load, when only the Spatial Span Backward was analyzed, the difference approached significance (F[1,56] = 2.76, p = .102, partial η^2 = .047, power = .372) (Table 2).

There were significant differences between groups on both Family Pictures I (F[1,56] = 7.517, p = .008, partial η^2 = .118, power = .769), and Family Pictures II (F[1,56] = 12.71, p = .001, partial η^2 = .185, power = .939), with the non-aggressive control group scoring higher on both. Additionally, significant differences were found between groups with the control group scoring higher on Logical Memory – 1st recall total score (F[1,56] = 4.60, p = .036, partial η^2 = .076, power = .558), and Logical Memory – thematic total score (F[1,56] = 4.98, p = .030, partial η^2 = .082, power = .592). However, when the DAST-20 and AUDIT were used as covariates these Logical Memory differences became only marginally significant (p = .074 and p =. 077, respectively) (Table 2).

There was a significant difference between the two groups on the Visual Delayed Subscale with the controls scoring higher (F[1,56] = 7.22, p = .009, partial η^2 = .114, power = .752). However, there was not a significant difference between groups on the Auditory Delayed Subscale (F[1,56] = .44, p = .508, partial η^2 = .008, power = .100), although the non-aggressive controls scored higher on average (Table 2).

There were no significant differences between groups on any of the major indices of the WMS-III, but the control group did score higher on all: Working Memory (F[1,56] = .306, p = .582, partial η^2 = .005, power = .085), Immediate Memory (F[1,56] = 1.20, p = .279, partial η^2 = .021, power = .189), and General Memory (F[1,56] = 2.36, p = .130, partial η^2 = .041, power = .326) (Table 2).

Table 2

Wechsler Memory Scale – III Means and Standard Deviations

	Impulsive Aggressors		Non-Aggressive Controls	
	M	*SD*	*M*	*SD*
WMS – III Subscales				
Auditory Immediate	105.55	6.17	105.79	16.10
Visual Immediate	95.55	8.07	100.31	13.49
Immediate Memory	100.90	6.52	103.93	13.44
Auditory Delayed	104.48	8.03	106.34	12.73
Visual Delayed	95.79**	9.51	102.72	10.12
Auditory Recog. Delayed	100.86	13.03	101.03	14.10
General Memory	99.67	10.24	102.75	10.55
Working Memory	107.90	11.60	109.62	12.12
WMS – III Subtests				
Logical Memory I – recall	9.21	2.16	10.38	2.92
Logical Memory I – 1st recall total	8.72*	2.14	10.21	3.05
Logical Memory I – thematic total	9.07*	2.95	10.90	3.28
Logical Memory II – recall	9.97	2.46	10.83	3.09
Family Pictures I – recall	9.79**	2.16	11.45	2.43
Family Pictures II – recall	9.52***	2.08	11.55	2.26
Letter Number Sequencing	11.03	2.41	11.13	2.28
Spatial Span	11.79	2.19	12.17	1.97
Spatial Span Backward	11.89	2.77	12.93	1.89

Note. WMS-III Subscales (M = 100, SD = 15), WMS-III Subtest scaled scores (M = 10, SD = 3); * denotes significant differences from controls ($p \leq 0.05$); but when the AUDIT and DAST-20 were used as covariates the differences from controls became only marginally significant ($p \leq 0.08$); ** denotes significant differences from controls ($p \leq 0.01$); *** denotes significant differences from controls ($p \leq$ 0.001). Impulsive Aggressors (n = 29), Non-aggressive Controls (n = 29).

California Verbal Learning Test – II. Major CVLT indices were analyzed using multivariate ANOVA. The only index that was significantly different between groups was Long Delay Free Recall ($F[1,56] = 5.99$, $p = .018$, partial $\eta^2 = .097$, power = .672), with the controls scoring higher than impulsive aggressors (Table 3).

Table 3

California Verbal Learning Test – II Means and Standard Deviations

	Impulsive Aggressors		Non-Aggressive Controls	
Index	*M*	*SD*	*M*	*SD*
Immediate Free Recall Total	56.31	8.16	60.69	9.68
Short Delay Free Recall	0.52	0.75	0.79	0.81
Short Delay Cued Recall	0.34	0.80	0.58	0.80
Long Delay Free Recall	0.26*	0.75	0.74	0.74
Long Delay Cued Recall	0.19	0.80	0.53	0.67
Total Recognition Discriminability	0.41	0.72	0.66	0.60

Note. Except for Immediate Free Recall Total (a *T* score; $M = 50$, $SD = 10$) all scores are *Z* scores; * denotes significant differences from controls ($p \leq 0.05$). Impulsive Aggressors ($n = 29$), Non-aggressive Controls ($n = 29$).

Wechsler Abbreviated Scale of Intelligence. Multivariate ANOVA was conducted to analyze the four subtests of the WASI. There was a significant difference between groups on Vocabulary ($F[1,56] = 11.49$, $p = .001$, partial $\eta^2 = .170$, power = .915), but not on Similarities ($F[1,56] = 2.71$, $p = .105$, partial $\eta^2 = .046$, power = .367), Block

Design (*F*[1,56] = 3.39, $p = .071$, partial $\eta^2 = .057$, power = .440), nor Matrix Reasoning (*F*[1,56] = .13, $p = .717$, partial $\eta^2 = .002$, power = .065). Non-aggressive controls did score higher on all subtests (Table 4).

Table 4

Wechsler Abbreviated Scale of Intelligence Means and Standard Deviations

	Impulsive Aggressors		Non-Aggressive Controls	
Indices and Subtests	*M*	*SD*	*M*	*SD*
Vocabulary Subtest	50.28***	7.29	57.31	8.47
Similarities Subtest	53.97	6.72	56.79	6.35
Verbal IQ	103.00**	8.77	111.14	10.30
Block Design Subtest	54.34	6.49	57.83	7.86
Matrix Reasoning Subtest	55.31	4.72	55.76	4.65
Performance IQ	107.14	7.69	111.38	9.09
Full Scale IQ	106.00***	6.49	113.03	8.40

Note. WASI Subtest scores (*T* scores; $M = 50$, $SD = 10$), WASI IQ scores ($M = 100$, $SD = 15$); ** denotes significant differences from controls ($p \leq 0.01$); *** denotes significant differences from controls ($p \leq 0.001$). Impulsive Aggressors ($n = 29$), Non-aggressive Controls ($n = 29$).

The indices of the WASI were analyzed using univariate ANOVAs. The difference between groups on Verbal IQ was significant (*F*[1,56] = 11.15, $p = .002$, partial $\eta^2 = .166$, power = .907), as was the difference on Full Scale IQ (*F*[1,56] = 12.74, $p = .001$, partial $\eta^2 = .185$, power = .939). However, the difference between groups was non-significant on Performance IQ ($F[1,56] = 3.68$, $p = .060$, partial $\eta^2 = .062$, power = .470). The control group scored higher on all indices (Table 4).

Study Two

Measures of Attention

Multivariate ANOVA was conducted on the major scales of the CPT-II. No significant differences were found between groups: Commissions ($F[1,56] = .243$, $p = .624$, partial $\eta^2 = .004$, power = .077), Omissions ($F[1,56] = .51$, $p = .479$, partial $\eta^2 = .009$, power = .108), nor Hit Rate ($F[1,56] = .45$, $p = .503$, partial $\eta^2 = .008$, power = .102).

Measures of Working Memory Accuracy and Reaction Time

Accuracy and reaction times of the *n*-back task were analyzed with repeated measures ANOVAs. However, because the 3-back was added late in the experiment, it was analyzed separately by univariate ANOVA. There were no significant differences between groups on accuracy found on the 0-2-back ($F[1,51] = 1.81$, p = .184, partial $\eta^2 = .034$, power = .262), nor 3-back ($F[1,41] = .62$, $p = .433$, partial $\eta^2 = .015$, power = .121), although the controls were more accurate on all tasks. Similarly, there were no significant differences between groups on reaction times found on the 0-2-back ($F[1,51] = .03$, $p = .860$, partial $\eta^2 = .001$, power = .053), nor the 3-back ($F[1,41] = .38$, $p = .543$, partial $\eta^2 = .009$, power = .092). Trends can be seen in the following graphs (Figures 3 and 4).

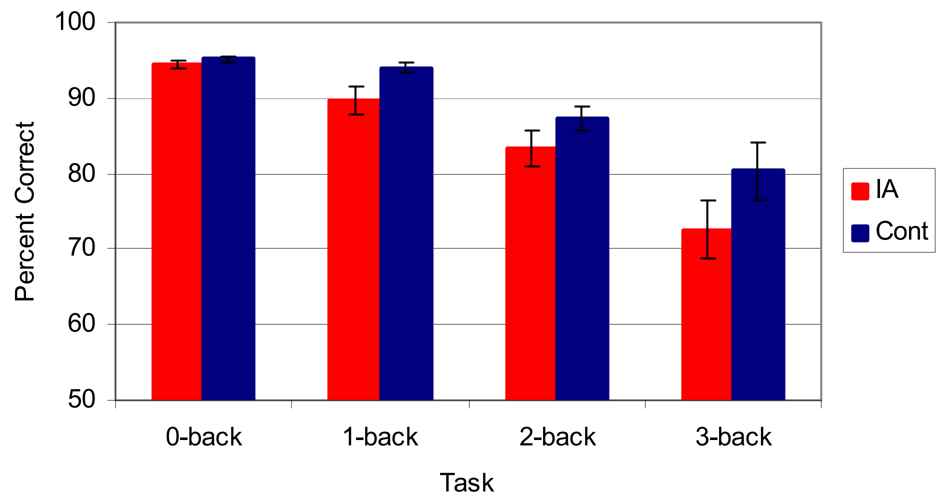


Figure 3. *n*-back accuracy rates by working memory load.

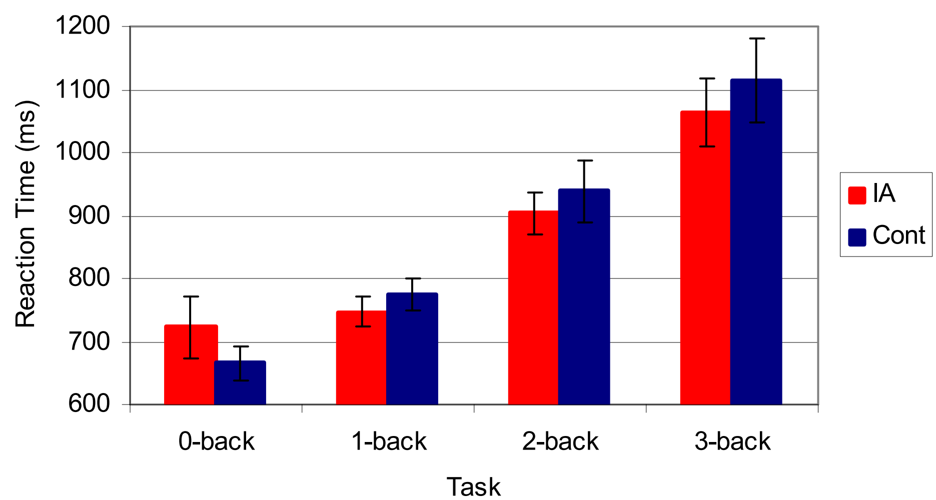


Figure 4. *n*-back reaction time by working memory load.

Multivariate ANOVAs were conducted on the accuracy of the Simultaneous and Sequential SMT as well as the reaction time of the Simultaneous SMT (reaction time is not measured for the Sequential SMT). There was no significant difference in accuracy ($F[1,55] = .99$, $p = .324$, partial $\eta^2 = .018$, power = .165) nor reaction time ($F[1,55] = 1.09$, $p = .300$, partial $\eta^2 = .019$, power = .177), between groups for the Simultaneous

SMT. However, there was a significant difference in accuracy between groups on the Sequential SMT, with the control group scoring higher: (F[1,55] = 3.81, p = .056, partial η^2 = .065, power = .484) (Figure 5).

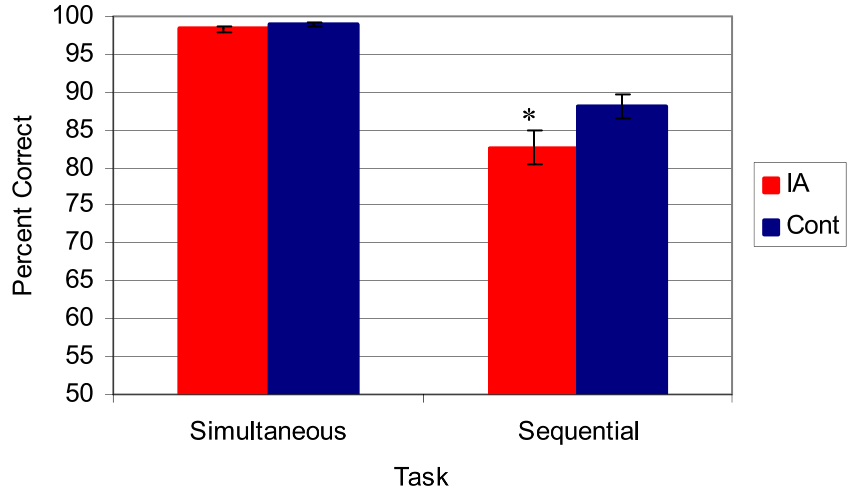


Figure 5. Spatial Memory Task accuracy rates for both static and working memory conditions. * denotes significant differences from controls ($p \leq 0.05$).

Measures of Psychophysiology

For the *n*-back task, the typical P300 topography was observed (Fz < Cz < Pz). In fact, the amplitude at Fz was so much smaller in comparison to Cz and Pz that it was decided to only use Cz and Pz in most analyses. Amplitude and latency of the P300 component of the ERP was analyzed using repeated measures ANOVA. Again, because the 3-back was added late, it was analyzed separately as its own repeated measures ANOVA. There were no significant between group amplitude (F[1,49] = .007, p = .932, partial η^2 = .000, power = .051), nor latency (F[1,49] = .27, p = .605, partial η^2 = .006, power = .080) differences for the 0-2-back tasks. When analyzing the 3-back it was discovered that there were significant outliers on amplitude for this task, one from each group, and so they were removed from the analysis. However, similar to the 0-2-back tasks, there were no significant differences in amplitude ($F[1,35] = .18$, $p = .673$, partial $\eta^2 = .005$, power = .070) (Table 5) nor latency ($F[1,37] = .21$, $p = .651$, partial $\eta^2 = .006$, power = .073) (Table 6).

Table 5

Group Amplitude Means (Standard Deviations) at Pz and Cz Electrodes

	Match		Non-match	
	IA	Cont.	IA	Cont.
Pz Amplitude (µV)				
0-back	5.75 (3.88)	5.84 (3.45)	4.98 (3.00)	5.34 (3.38)
1-back	5.67 (3.25)	5.86 (3.64)	5.06 (3.31)	5.36 (3.57)
2-back	5.31 (3.71)	5.49 (3.07)	4.65 (3.67)	4.86 (3.62)
3-back	4.73 (3.99)	5.38 (3.44)	4.74 (3.95)	3.53 (3.09)
Cz Amplitude (µV)				
0-back	3.30 (3.14)	3.43 (3.30)	3.21 (3.21)	3.06 (2.53)
1-back	3.64 (2.80)	4.48 (3.83)	3.79 (2.10)	4.06 (4.17)
2-back	4.87 (2.52)	4.26 (3.93)	4.74 (2.41)	4.44 (3.74)
3-back	4.74 (2.77)	3.53 (3.36)	4.05 (2.53)	3.16 (2.37)

Note. IA = impulsive aggressors ($n = 27$ for 0-back, $n = 26$ for 1-back, $n = 27$ for 2-back, $n = 18$ for 3-back) Cont. = non-aggressive controls ($n = 28$ for 0-back, $n = 27$ for 1-back, $n = 26$ for 2-back, $n = 21$ for 3-back).

Table 6

Group Latency Means (Standard Deviations) at Pz and Cz Electrodes

	Match		Non-match	
	IA	Cont.	IA	Cont.
Pz Latency (ms)				
0-back	330.26 (31.11)	338.93 (38.23)	342.59 (29.71)	335.57 (41.64)
1-back	342.04 (35.96)	337.56 (33.66)	330.62 (35.68)	335.44 (42.90)
2-back	345.15 (23.13)	350.00 (40.91)	348.04 (29.84)	347.08 (49.38)
3-back	335.56 (27.74)	335.95 (51.34)	333.18 (25.84)	339.10 (53.57)
Cz Latency (ms)				
0-back	326.30 (32.17)	345.36 (38.25)	329.44 (27.87)	322.29 (53.04)
1-back	335.65 (39.99)	332.15 (42.60)	335.38 (30.75)	331.11 (36.57)
2-back	346.74 (28.60)	344.28 (43.51)	339.74 (27.38)	351.92 (43.79)
3-back	336.00 (32.65)	321.86 (44.58)	332.33 (36.46)	322.86 (41.51)

Note. IA = impulsive aggressors (n = 27 for 0-back, n = 26 for 1-back, n = 27 for 2-back, n = 18 for 3-back) Cont. = non-aggressive controls (n = 28 for 0-back, n = 27 for 1-back, n = 26 for 2-back, n = 21 for 3-back).

Interestingly, when comparing amplitude, there was a significant within-groups interaction effect between group and stimulus (F[1,35] = 4.16, p = .049, partial η^2 = .106, power = .509). Paired-samples t-tests were conducted to evaluate the differences between the two stimulus types (match and non-match) for each group. For impulsive aggressors, the mean for non-match (M = 4.05, SD = 2.50) did not differ from the mean for match (M = 4.05, SD = 2.42), t(16) = .004, p = .997. For controls, however, the results indicated that the mean for non-match (M = 3.55, SD = 2.34) was significantly less than the mean for match (M = 5.16, SD = 2.81), t(19) = -2.39, p = .027 (Figures 6 and 7).

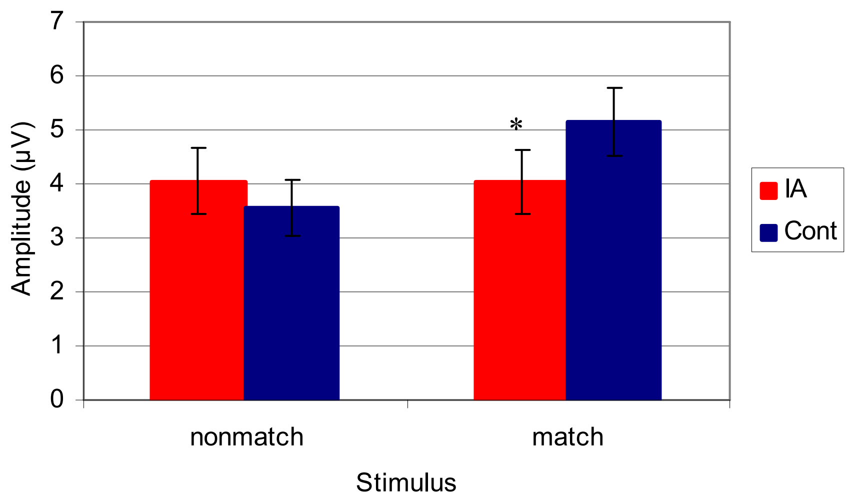


Figure 6. 3-back amplitude by stimulus. * denotes significant differences from controls ($p \leq 0.05$).

Topographical Mapping of Frontal Activation

Repeated measures ANOVAs were conducted on Fz amplitude for match stimuli. No significant differences were found between groups (F[1,37] = 2.13, p = .153, partial η^2 = .054, power = .295). However, frontal lobe differences between the two groups were clearly seen when midline amplitudes were compared (Figure 8).

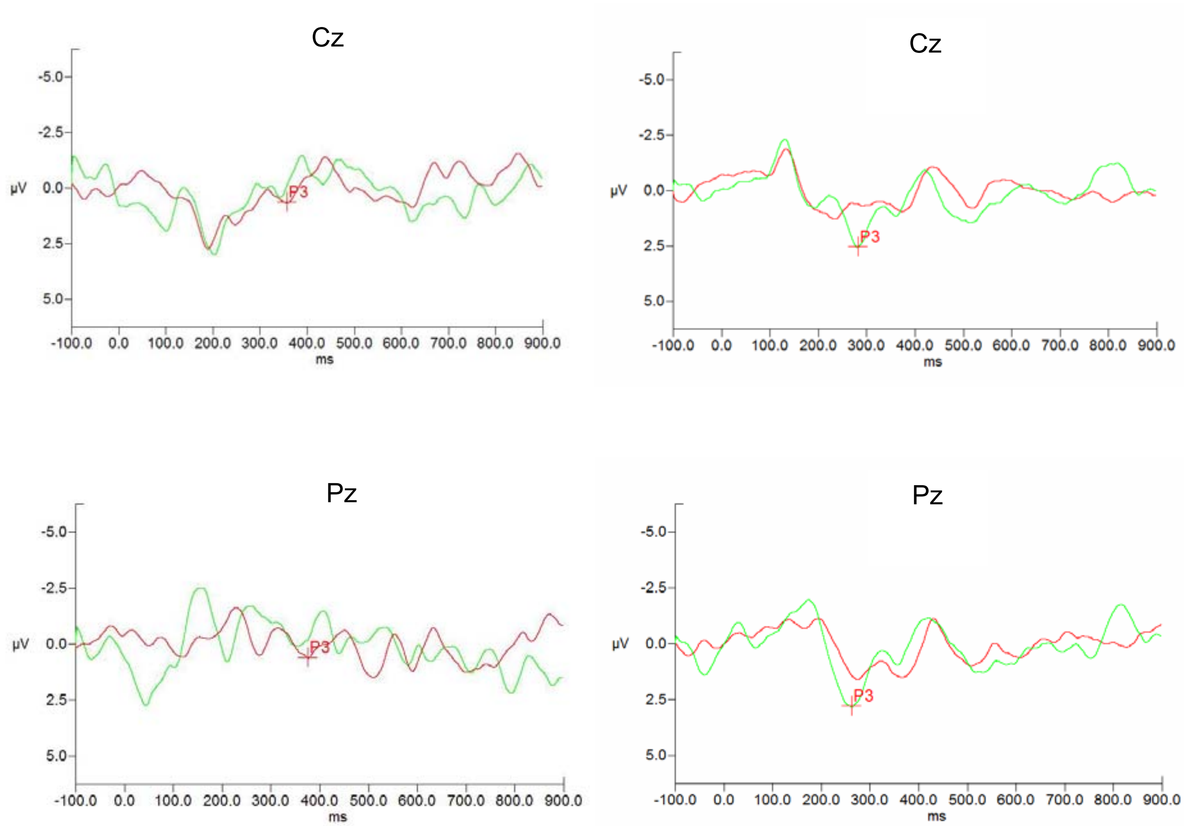


Figure 7. Representative ERP waveforms of each group for 3-back task match (green) and non-match (red) stimuli at Cz and Pz electrodes; impulsive aggressors are on the left, non-aggressive controls are on the right.

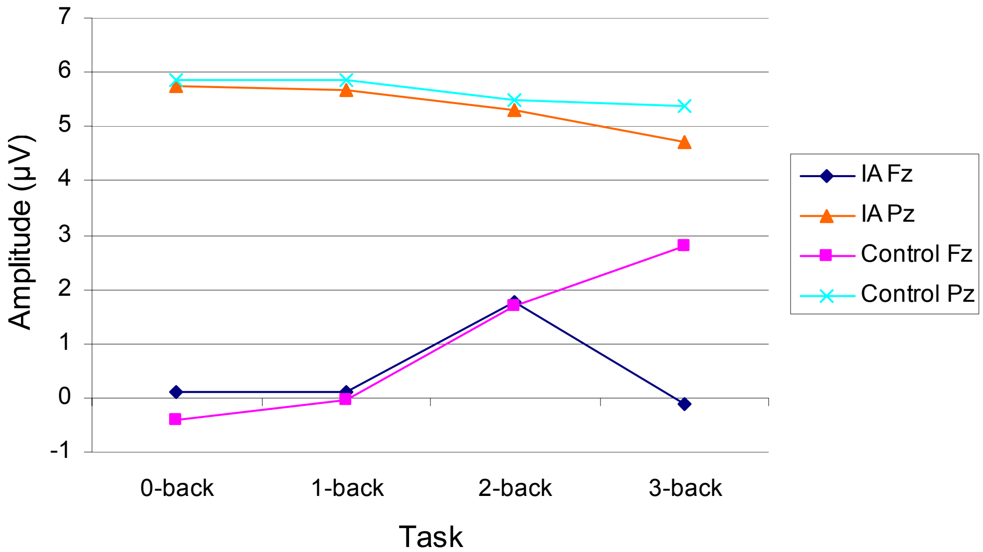
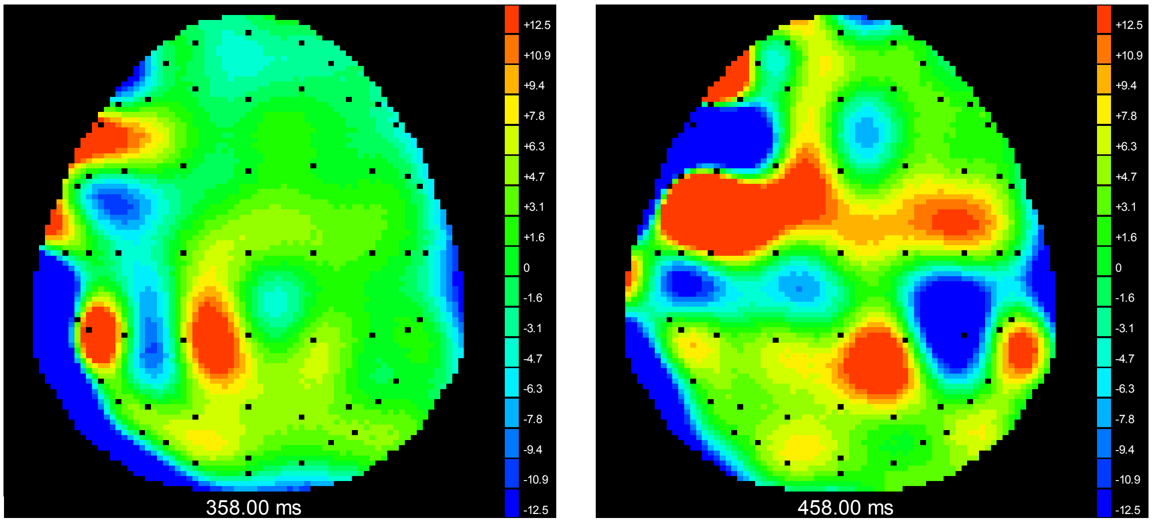


Figure 8. P300 amplitudes by task at Fz and Pz electrodes.

The difference between group’s frontal activation became even more apparent with a comparison of topographical maps of brain activity during the 3-back task for matched stimuli (Figure 9).



Impulsive Aggressors Non-aggressive Controls

Figure 9. Topographical maps of differential activation of impulsive aggressors and non-aggressive controls on 3-back matched stimuli. Maps were taken at the peak P300 of the Pz electrode for each group’s average.

CHAPTER FOUR

Discussion and Conclusions

Discussion

The results of the present study suggest impulsive aggressors (IA) have a functional working memory deficit. IAs scored lower on all measures of working memory and significantly lower on the Sequential SMT. Additionally, as working memory load increased, the difference between group scores also increased and the impulsive aggressors seem to reach a point that they were cognitively overloaded. During the *n*-back task of spatial working memory, as load reached a maximum, controls activated more and more of their frontal resources. This was not seen in the impulsive aggressors. Impulsive aggressors also scored lower than controls on several measures of verbal memory. Finally, during the 3-back task, non-aggressive controls had higher P300 amplitudes for matched stimuli than non-matched – this was not seen in the impulsive aggressors, indicating they react to low and high probability stimuli the same.

Working Memory

It was hypothesized that the impulsive aggressive group would score lower than the control group on *all* measures of working memory, both verbal and spatial. This was not the case. The only test of working memory in which the difference between groups was statistically significant was on the Sequential SMT. The findings of Aronen et al. (2005) may shed some light on why the between group differences for the n-back were not significant. They studied 66 school children and administered both a visual and an auditory n-back task and then correlated their scores on these to a variety of teacher reported academic, behavioral, and emotional scores. They found that neither form of the *n*-back correlated with externalizing problems, (measured by delinquent and aggressive syndrome scales). They both did correlate with attention (which included problems with impulsivity).

Interestingly, on all the working memory tests the control group did better. Also, as working memory load increased, the difference between group scores increased. It is possible that if the 3-back had been given to all subjects or even if a 4-back task had been added, the difference between accuracy scores would have reached significance. Further illustrating this point is the fact that there was a significant difference between group scores on the Sequential SMT, but not on the Spatial SMT nor on the Spatial Span task of the WMS-III. The Sequential subtest is almost the same as Spatial Span – Forward except that it is done on a computer and that in Spatial Span, once the participant has missed two or three trials the test is completed. In Sequential the testing period is not truncated by the number of misses so those individuals who did not go very far in Spatial Span had no choice but to keep going when doing Sequential, producing a significant difference on this task and not the other.

It appears that spatial (and possibly verbal) working memory may be impaired in impulsive aggressors to some degree. Follow-up studies may include a more extensive study specific to working memory in which principal components analyses are used in order to discover which precise working memory deficits can identify impulsive aggression. This would be particularly useful if the deficits could be identified early on in life to predict future impulsive aggressive behavior and so that treatment could be started before the behavior becomes a serious problem. Not only could the impulsive aggression itself be treated, but also understanding the exact memory deficits will allow for increased ability to help the individuals develop coping strategies.

The working memory problems apparent in this group may also be seen as a manifestation of executive dysfunction. Owen, Morris, Sahakian, Polkey, & Robbins (1990) studied executive functions and working memory in patients who had undergone unilateral amygdalo-hippocamptomy and suggested that spatial working memory is separable into executive and short-term memory components. As there were no significant differences between groups on short-term memory tasks, and differences only became apparent with increasing working memory load, thus placing higher demands on executive functions, it seems likely that the working memory impairment found in this group is mainly a manifestation of executive dysfunction.

Verbal Memory

In the verbal memory domain, it was hypothesized that if differences existed they would be seen on the more cognitively demanding tests of the WMS-III and CVLT-II. It was further hypothesized that impulsive aggressors would score lower on both the Vocabulary and Similarities subtests of the WASI.

It is interesting that differences were found between groups on both Family Pictures subtests. One possible explanation is that the difference really reflects a difference in verbal memory. Even though Family Pictures in mainly considered a visual memory task, it has significant verbal loadings. As subjects are asked to view pictures of the family engaged in various activities, they not only encode them visually, but verbally as well. Dulay et al. (2002) used stepwise regression to examine various predictors of

Family Pictures scores, including other WMS-III scores and found that Logical Memory was the best predictor and accounted for 26.6% (LM-I for FP-I) and 30.3% (LM-II for FP-II) of the variance. Another predictor included Letter-Number Sequencing. This is in-line with another possible explanation for the difference between groups on Family Pictures, that the difference is really a reflection of a difference in working memory ability (Miyake, Frieman, Rettinger, Shah, & Hegarty, 2001). It has been argued that any task placing demands on visuospatial short-term memory necessarily require the use of working memory, thus the difference between groups on the Family Pictures subtests may be seen as a reflection of a difference in working memory abilities. This interpretation was also demonstrated in other portions of this study.

The difference between the Visual Delayed Subscale was also significant. This subscale is composed of scores for Family Pictures II – recall and Faces II – recognition. Even though the controls did score higher on Faces II, the difference between scores was negligible ($F[1,56] = .19$, $p = .669$). Thus, the difference in Visual Delayed Subscale was mainly a reflection of the great difference in Family Pictures II - recall scores.

Additionally, there were differences on Logical Memory – 1st recall total score and Logical Memory I – thematic total score. This was not consistent with the hypothesis that the differences would be seen in the more cognitively demanding of the tasks, Logical Memory II. Although the control group did score higher on Logical Memory II, the difference was not significant. However, the specific differences found in Logical Memory I are interesting. In the Logical Memory subtest there are two short stories read. The first one is read only one time, the second is read twice. After each time, the subject repeats as much of the story as possible. They are given two main scores, a unit score (a total of each element of the story they remember) and a thematic score (a total of general ideas from the story that they remember).

For the Logical Memory – 1st recall total score, the second recall of story two was not included, and so did not include so much of a learning element as the Logical Memory – recall score. That the controls did significantly better than the impulsive aggressors on this measure but that their Logical Memory I– recall and Logical Memory II - recall scores were not significantly different may imply that impulsive aggressors do not learn verbal information as readily as non-aggressive controls, but with repetition they can learn it and retain it just as well once it is encoded.

That there was a significant difference between Logical Memory I – thematic total score and not between Logical Memory I – recall indicates that impulsive aggressors remembered perhaps slightly more details within each theme which they remembered, but remembered fewer themes overall. This is in-line with what others have found in regards to impulsive aggressors low scores in language and reading comprehension (Lewis et al., 1980). Additionally, in their study comparing impulsive aggressive to non-impulsive aggressive patients from a maximum security hospital and non-aggressive controls, Dolan and Anderson (2002) also found impulsive aggressors have statistically significant lower scores on Logical Memory – immediate recall on the WMS-R. It could also be argued here that these Logical Memory deficits are not purely verbal, but again, that a working memory deficit exists. "It is frequently asserted that the comprehension of both written and spoken language depends on some form of working memory" (Baddeley, 1986, p. 54).

There were no between-group differences on the other verbal subset of the WMS-III, Verbal Paired Associates, either the immediate or delayed recall. On the first administration, Verbal Paired Associates I, the word pairs are read and recalled five times. There were differences between group scores here with the controls scoring higher, but the difference was not significant, as by the end, all subjects were able to memorize the word pairings. However, on the second administration, there is just a recall and recognition component. Only one subject ever missed any items here. Thus, there was too great a ceiling effect for this subtest to provide any meaningful results.

The difference in the CVLT-II measure of Long Delay Free Recall provided further evidence of verbal deficits in the impulsive aggressive group. Verbal deficits in an impulsive aggressive population were also studied using the CVLT by Kockler and Stanford (in press). The sample used in their study consisted of 170 self-referred, court referred, and clinic referred physically aggressive adults. Using principal components analysis, they found low scores on several CVLT measures were correlated to the Attentional and Non-planning Impulsivity subscales of the BIS-11. In the current research, having studied a sample of high functioning college students and still finding a difference in Long Delay Free Recall clearly indicates a deficit exists.

Additionally, significant between-group differences were found for the Vocabulary subtest of the WASI. Vocabulary is a good measure not only of verbal abilities, but also of long-term semantic memory. The Similarities subtest also assesses these abilities, but it loads a little less on memory and requires a little more critical thinking skill. Interestingly, although impulsive aggressors did score lower on Similarities, the score was not significantly different from the non-aggressive controls seeming to indicate that the verbal deficit of impulsive aggressors is more in the area of memory than critical thinking. Even though the non-aggressive controls did score significantly higher on FSIQ, it is believed that this is mainly a reflection of the non-aggressors significantly higher Vocabulary score as there was no significant difference from impulsive aggressors on Matrix Reasoning, Block Design, nor Performance IQ.

Whether the differences found in verbal memory were a reflection of working memory and/or executive function or truly based on difference in verbal ability and memory is unclear. Although the differences seen in Family Pictures and Logical Memory could be explained by working memory differences, neither Long Delay Free Recall nor Vocabulary are short-term memory tasks. Another study of verbal memory while controlling for executive functioning is warranted.

Psychophysiology

Contrary to the hypothesis, there were no significant differences between group amplitudes or latencies at any of the midline electrodes. This is different from the results of most previous researchers on impulsive aggression using P300 tasks that have found both decreased latencies and amplitudes (Barratt et al., 1997b; Gerstle et al., 1998; Mathias & Stanford, 1999), even in college samples (Helfritz, 2005). Watter et al. (2001) studied the *n*-back and found it to be a dual task, both a matching task and a working memory task. Most tasks designed to elicit a P300 are singular, often matching tasks. The duality of the *n*-back causes a division of cognitive resources, only a percentage of which are measured by the midline P300. This may be why the difference in amplitude and latency is not seen here when it has been so well documented previously.

In conjunction with previous research (Barratt et al., 1997b; Mathias & Stanford, 1999), there was a difference in amplitude between match and non-match stimuli for the non-aggressive control group during the 3-back task while no difference was seen in the impulsive aggressive group. Impulsive aggressors appear to treat all stimuli the same, not distinguishing between low and high probabilities. Barratt et al. (1997b) suggest that one possible reason for this difference is that impulsive aggressors are under-aroused, and it is this sub-arousal that leads to their sensation-seeking and impulsive behaviors.

Although the differences between Fz amplitudes were not statistically different, and although admittedly interpretation of topographical mapping is subjective, the evidence in this case appears quite convincing from the maps, and supported by the P300 waves as well as by the mean amplitudes at electrode sites, that there was a clear difference between groups during the 3-back task as to cognitive sources being frontally allocated. It appears once again that when working memory load reaches a maximum, impulsive aggressors reach a point that their cognitive resources can no longer sustain the task processing. Several studies have documented the relationship between impulsivity and working memory. For example, in their study of an aggressive population Kockler and Stanford (in press, p. 13) found that impulsivity and working memory were inversely correlated and said "individuals with higher scores of attentional impulsiveness are more likely to have difficulties with removing irrelevant information from working memory – resulting in cognitive overload." Additionally, "the inability to plan for the future – as measured by nonplanning impulsivity subscale – was more times than not negatively related to working memory functions. This is an important finding in that it demonstrates how an individual's ability to make appropriate decisions depends largely on working memory capabilities" (Kockler and Stanford, in press, p. 13).

That even during a high working memory load task, impulsive aggressors do not recruit frontal lobe resources provides further evidence to the frequent findings of others that there is impairment in the frontal cortex of the impulsive aggressive population (Barratt et al., 1997b; Bechara et al., 2000; Birnbaum et al., 2004; Dolan & Anderson, 2002; Eslinger et al., 1999; Giancola et al., 1998; Kim, 2002; Krynicki, 1978; Raine et al., 2001; Seguin et al., 2004). According to Seguin et al. (1995), word retrieval is a function of the left dorsolateral frontal cortex. The topographical maps are not accurate enough to pinpoint exact areas of brain function or dysfunction, but the lack of frontal activity as indicated by the maps does demonstrate a brain activity contribution to the difference in scores on Long Delay Free Recall on the CVLT-II. Additionally, that the difference was mostly seen on the left side was in accordance with the findings of Dolan and Anderson (2002) and Seguin et al. (1995). Dolan and Anderson (2002) said the verbal abilities impacted by this left hemisphere impairment include concept formation. This would influence the difference in scores on both the Vocabulary subtest of the WASI and the Family Pictures subtests of the WMS-III as observed.

Conclusions

In this college sample there were many high functioning impulsive aggressors and so some of the deficits that may be present in the impulsive aggressive population as a whole would not necessarily be observed in this sample. However, when their working and verbal memories are "overloaded", these deficits become apparent. Included were verbal deficits as seen on subtests of the WMS-III (Logical Memory I – 1st recall and thematic total and Family Pictures I and II), CVLT-II (Long Delay Free Recall), and WASI (Vocabulary).

Working memory deficits were also seen as impulsive aggressors' scores were significantly less accurate on the Sequential task of the SMT. Further, controls increasingly outperformed impulsive aggressors on the *n*-back as task load increased. Additionally, impulsive aggressors responded to low probability stimuli to the same degree as to high probability stimuli during the 3-back while non-aggressive controls exhibited differentiated response to the two types of stimuli. Finally, when impulsive aggressors appeared to reach a working memory "overload" during the 3-back task, they failed to properly recruit frontal lobe resources. This finding is interesting in-light of previous findings that impulsive aggression is linked to frontal lobe impairment and that impulsive aggressors commonly do poorly on tests of executive function (which is largely controlled by the prefrontal cortex.)

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