ABSTRACT

Frontal Lobe Asymmetry and Impulsive Aggression:
A Reinforcement Sensitivity Study

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The current study compared impulsive aggressive individuals and nonaggressive controls using frontal cortical EEG activity. Impulsive aggression is a reactive or emotionally charged violent response characterized by a loss of behavioral control. Previous physiological studies have found impulsive aggressors (IAs) have sensory and informational processing deficits. Undergraduate male volunteers (n = 15 IAs, n = 15 controls) completed a resting EEG and two affective picture tasks intended to manipulate emotional state. IAs showed more right frontal cortical activity than controls at lateral-frontal electrodes at rest [$t(28) = 2.470$, $p = .020$] and had similar asymmetry indices throughout the two emotional paradigms [$t(14) = .890$, *ns*]. Controls, however, were able to engage the Behavioral Inhibition System (BIS) during withdrawal-related stimuli [$t(14) = 2.576$, $p = .022$]. An interaction between group and picture task [$F(2, 14) =$ 3.818, $p = .028$] reinforced this result. Results indicated that IAs have an overactive BIS and thus cannot appropriate the proper biological systems in response to emotional stimuli. Future directions are discussed.

Frontal Lobe Asymmetry and Impulsive Aggression:
A Reinforcement Sensitivity Study

by

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A Dissertation

Approved by the Department of Psychology & Neuroscience

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Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of

Doctor of Philosophy

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December 2013

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ACKNOWLEDGMENTS

It takes a village to write a dissertation. This project would have been impossible without the direction and support of my mentor, Dr. Matthew S. Stanford; chair Dr. Jaime L. Diaz-Granados; committee members Dr. Sara L. Dolan, Dr. Jon E. Singletary, Dr. Charles A. Weaver III, and Dr. Jim H. Patton; as well as the remaining faculty in the Psychology and Neuroscience Department at Baylor University. Their support, patience, input, and constructive criticism were crucial to the understanding and completion of this study.

Along with superb faculty, many graduate and undergraduate students have assisted in data collection and analysis. Thanks to Baylor colleagues Megan Haggard, Mitchell Todd, Lindsey Hicks, and Brian Rundle for their assistance, grace, and compassion. Thanks to Dr. Nate Anderson who taught me everything I know about psychophysiology. My abundant thankfulness goes to Drs. Hillary Blakely, Jordan LaBouff, and Megan Johnson Shen for being my academic inspiration. A heap of gratitude goes to the Baylor Graduate School and the Graduate Student Association, especially Adeline Meira, Shelly Adams, Dr. Chris Rios (Ph.D.!), Sandra Harman, Loretta Volcik, Rachel Whitenton, and Dr. Denny Kramer for five years of care, laughter, and free food. Finally, a special thanks goes to my family for their everlasting support and motivation from 2000 miles away.

To CRH, now and forevermore

CHAPTER ONE

Background and Significance

Personality Theories

The field of experimental psychology has a surplus of research on personality traits. One such motivation has been research differences in personality as underlying reasons for behavioral tendencies. One of the first psychologists to study personality, Allport (1937) took 4500 trait-like words characteristic of personality and found that he could organize them into one of three trait categories: *cardinal traits*, which are dominant traits that shape behavior; *central traits*, which are general characteristics found in every individual to some degree; and *secondary traits*, characteristics that are only seen under specific circumstances. Allport (1937; Allport & Odbert, 1936) hypothesized that this three-personality trait theory could effectively categorize human behavior, and with subsequent philosophical speculation could be used to model human motivation.

In the late 1940s, psychology was influenced by the advancement of statistical procedures when Cattell hypothesized that factor analysis could be applied to personality measures to discover fundamental personality traits that underlie behavior. Cattell (1957; 1965) used a subset of Allport's dictionary words classified as stable traits to construct 171 dichotomous scales. Then, using factor analyses, he consistently found personality contained five main factors (1965). These second-order factors have been identified and replicated using many variables (Goldberg, 1990; McCrae & Costa, 1987; Norman, 1967) and resulted in the following traits that are now known as the Big Five: Openness, the degree to which a person is curious or adventurous; Conscientiousness, the tendency to show self-discipline and aim for achievement; Extraversion, the degree to which a person is energetic and seeks stimulation of others; Agreeableness, the tendency to be compassionate and cooperative; and Neuroticism, the degree to which a person experiences unpleasant emotions easily, such as anxiety or anger (Costa & McCrae, 1992; Goldberg, 1993).

Around the same time, Eysenck (1967) developed another model of personality also utilizing factor analysis as the primary statistical procedure. Using a multitude of self-report measures, Eysenck's personality model (Eysenck, 1967) postulated two main dimensions of personality: Extraversion/Introversion (E), the degree to which a person is in need of external or internal stimulation, and Neuroticism/Stability (N), the tendency to be negatively emotionally affected. Eysenck believed that he could predict behavior in certain situations based on the degree to which individuals varied on each of these personality traits. He theorized that E and N could be plotted orthogonally in a 2-dimensional space to describe individual differences in behavior, with each end of the spectrum representing different levels of cortical arousal (Eysenck, 1967). For instance, those with high E scores would have less cortical arousal than those low on the dimension, thus creating a need for external stimuli (Eysenck, 1967; Hagemann, Hewig, Walter, Schankin, Danner, & Naumann, 2009; Zuckerman, 1991). Through testing this theory of E and N, Eysenck realized a third factor was necessary: Psychoticism (P), the tendency to be reckless, hostile, angry, or impulsive (Eysenck & Eysenck, 1976). Under Eysenck's personality model, these three dimensions of personality underlie all human behavior (1981). Eysenck theorized that differences in personalities were the cause for the range of conduct between individuals.

Behavioral Approach/Withdrawal

The abundance of previous research on personality indicates the importance of individual differences of such on behavior. Literature on both positive and negative affective traits are plentiful, but the distinction of what constitutes positive or negative affect has been a source of constant debate (Hagemann, Naumann, Thayer, & Bartussek, 2002), along with the specific brain mechanisms involved.

Carver and Harmon-Jones (2009) define affect as “a hedonic experience, a sense of valence, a subjective sense of positivity or negativity arising from an event,” (p. 183). Thus, those experiencing a positive affect would sense a feeling of satisfaction, and those experience negative affect would feel displeasure. Preceding affect is the event’s valence, eliciting the resulting emotion (Carver & Harmon-Jones, 2009; Davidson, 1998a). Valence is frequently viewed in terms of motivational systems that trigger affect (Alloy et al., 2009; Carver & Harmon-Jones, 2009; Coan & Allen, 2003; Harmon-Jones, 2003a; Harmon-Jones, 2003b). That is, an event that is positively valenced should induce behavior intended to experience it, whereas a negatively valenced event should trigger avoidant behavior.

Eysenck (1967; Eysenck & Eysenck, 1976) developed a personality theory using E, N, and P by using factor analysis to locate specific brain systems involved in controlling emotional behavior (Torrubia, Avila, & Caseras, 2008). Gray (1982) noted however those although these statistical analyses were useful in identifying independent personality factors, he could not accurately locate the dimensions of personality in different subsystems of the brain strictly by self-report alone. Using animal research to modify Eysenck’s theory, Gray (1970; 1978; 1982; 1987a; 1987b) hypothesized separate *systems*—instead of traits—that underlie human behavior. These systems, the behavioral approach system (BAS), the behavioral inhibition system (BIS), and the fight-flight system (FFS), contribute to personality and comprise the Reinforcement Sensitivity Theory (RST). The RST states that the degree to which a person finds specific stimuli reinforcing depends on their individual propensity to use each system. The BAS related to positive emotions and engaging behaviors that were involved in approaching desired rewards (Carver & White, 1994; Davidson, Ekman, Saron, Senulis, & Friesen, 1990). The BAS related to goal-directed movement and escape of punishment, and sometimes referred to as approach motivation (Carver & White, 1994). Lastly, the FFS comprised the sensitivity to all aversive stimuli (Alloy et al., 2009b; Gray, 1990). Gray (1972) theorized the BIS was the main aversive motivational system, organizing conditioned behaviors that are involved in avoiding unfavorable outcomes and resolving goal conflict (Carver & White, 1994), and thus also the system for eliciting behavior to avoid punishment. The BIS is also referred to as withdrawal motivation.

Because Gray (1972; 1987a,b; 1990; 1994) hypothesized that the BIS and BAS had strict ties with affective valence of the preceding events, Carver and White (1994) developed the Behavioral Inhibition System/Behavioral Activation System Scales (BIS/BAS Scales) to measure an individual's propensity to use each system based on a person's tendency to prefer positive or valenced events and typical reactions to such. The BIS, theorized as the aversive motivational system, was thought to involve strictly negative affective situations. The BAS, conjectured to be the system for goal-directed movement, involved behaviors pertaining to positive affect. The scales were thought to accurately indicate a person's willingness to engage in behaviors that were appropriate for the preceding valence.

Frontal EEG Cortical Asymmetry

Frontal resting electroencephalogram (EEG) activity is mainly used to study individual differences related to trait or trait-like measures to make inferences about emotional processes (Davidson, Schwatrz, Saron, Bennet, & Goleman, 1979). The majority of previous research focuses on examining individual personality traits with frontal asymmetry, like anger (Carver & Harmon-Jones, 2009; Harmon-Jones, 2007;), disgust and happiness (Davidson et al., 1990b), positive and negative affective situations (Gable & Harmon-Jones, 2008), stress responses (Verona, Sadeh, & Curtin, 2009), and aggression (Verona et al., 2009). Research that uses asymmetry as an individual difference related to psychopathology has focused on manic or depressive symptomology (Harmon-Jones, Abramson, Sigelman, Bohlig, Hogan, & Harmon-Jones, 2002; Peterson & Harmon-Jones, 2009), autism (Orekhova, Stroganova, Prokofiev, Nygren, Gillberg, & Elamn, 2009), and impulse control problems such as eating disorders (Silva, Pizzagalli, Larson, Jackson, & Davidson, 2002).

Most of the replicated literature centers on trait-dependent hypotheses in positive and negative affect research (Gable & Harmon-Jones, 2008; Tomarken, Davidson, Wheeler, & Doss, 1992), although both state and trait investigations occur. Generally, half of the variance found during frontal cortical activity research is due to state influences, with the residual half attributed to trait influences (Hagemann et al., 2009). The bulk of the previous literature agrees that resting frontal cortical activity is indicative of affective style in terms of individual approach or withdrawal tendencies (Coan &

Allen, 2004; Coan, Allen, & McKnight, 2006; Davidson, 1993; Davidson, 1998a,b). Davidson (1993; 1998a; 1998b) proposed a model of approach and withdrawal motivation in regards to resting EEG activity with increased left frontal activity indicating a predisposition to approach a stimulus, and increased right frontal activity relating to withdrawing from a stimulus, regardless of the individual's state or trait.

Accepting the presupposition that frontal asymmetry is indicative of an individual's tendency to use approach- or withdrawal-related tendencies (Coan et al., 2006) and related to affective trait research, Harmon-Jones (2003b) updated Davidson's theory by proposing three models of frontal asymmetry in response to the research: the *valence model*, the *motivational direction model*, and the *valenced motivation model*, each theorizing that the propensity to use the right or left frontal lobe is due to valence, motivational systems, or a combination of both. For ease of understanding the nuances of each theorized model, see Table 1.

Table 1
Models of Frontal Asymmetry

	Frontal Cortical Region	
Model	Left	Right
Valence	Experiencing positive affect	Experiencing negative affect
Motivational Direction	BAS-related behaviors	BIS-related behaviors
Valenced Motivation	BAS-related behaviors and positive affect	BIS-related behaviors and negative affect

Carver and White (1994) intended to measure self-reported affective valence with their BIS/BAS Scales, however Harmon-Jones and colleagues (Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001) demonstrated that the BAS was activated during anger, an affect previously thought to be negatively valenced, showing that simply affective valence does not fully explain behavioral motivation tendencies. Harmon-Jones (2003b) noted that not all emotions act in a valenced motivational way, as anger is negative in valence but evokes left frontal cortical region activity (e.g., Carver & Jones, 2009; Harmon-Jones, 2004a,b). Thus, both the *valence* and *valenced motivation* models have less credence than the *motivational direction* model (Davidson, 2004).

Anger

Anger is characterized as an emotion brought on by frustration in regards to expectations (Siegel, 1986). Anger is typically regarded as a negatively valenced emotion (Buss & Perry, 1992; Harmon-Jones, 2003b), although anger could be used in defensive situations (Tomarken & Davidson, 1994) and consequently be regarded as positive. This ambiguity is why research utilizing affective valence and frontal lobe asymmetry should clearly define anger.

Harmon-Jones and Allen (1998) used the Buss Perry Aggression Questionnaire (BPAQ: Buss & Perry, 1992) to assess trait anger then recorded resting frontal activity in adolescents. High levels of anger were related to increased left cortical activity and decreased right activity. This initiated a movement of research on frontal asymmetry and anger, as the left frontal cortical region had previously been thought to be strictly positively valenced and approach-motivated. Harmon-Jones (2004a; Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003) replicated these results showing that at mid-frontal and lateral-frontal sites, trait anger related to greater left frontal EEG activity, postulating that highly angry individuals see anger as a positive trait, with cortical activity reflecting this. Harmon-Jones (2004a) tested this conjecture by developing the Attitudes Towards Anger scale (ATA: Harmon-Jones, 2004a). Although the scale was valid and reliable, a positive attitude towards anger did not correlate with left frontal cortical activity, and thus the relationship between trait anger and left frontal cortical activity was hypothesized to be due to an approach-motivated direction (and tendency to use the BAS) (Harmon-Jones 2004a,b). Harmon-Jones (2004a) used this as evidence for the motivational direction model, in line with the RST.

Aggression

Anger is closely related to aggression (Buss & Perry, 1992; Jensen-Campbell, Knack, Waldrip, & Campbell, 2007), as aggression is typically a negative consequence of anger (Berkowitz, 2000). As anger was shown to be an approach-motivated behavior, Harmon-Jones (2003a) found that when using the BIS/BAS Scales (Carver & White, 1994), trait aggression was negatively related to BIS and positively related to BAS. Thus, aggression was believed to be "caused by individual differences in approach motivation" (p. 1002, Harmon-Jones, 2003a). BIS did not negatively correlate with anger, suggesting that the BIS inhibits physically aggressive behaviors only. Indeed, Coan and Allen (2003) also found that high levels of trait BAS sensitivity were associated with a likelihood of aggressive behavior—aggression as a means to an end.

Similarly, Harmon-Jones and Sigelman (2001) purposefully offended participants and then asked them to assign an aversive-tasting drink to the insulter. After the insult, a resting EEG showed those with higher left frontal activity designated a more bitter tasting drink to the offender. The researchers defined this as an aggressive act and hypothesized that anger and the BAS were associated with offensive aggression (Harmon-Jones & Sigelman, 2001).

Impulsivity

The first relatively modern definition of impulsivity was by Emil Kraepelin in his book *Lehrbuch der Psychiatrie,* translated into English in the early twentieth century by Defendorf (1904). Kraepelin described what he called *impulsive insanity*, in which acts "are performed because of an irresistible impulse….[Impulses] appear suddenly and appear quickly…causing the actions to appear unpremeditated, purposeless, and even absurd" (p. 389). Kraepelin delineated impulsive insanity from criminal behavior, stating criminal behavior stems from selfish intentions.

Slightly later in the twentieth century, Eugene Bleuler's *Textbook of Psychiatry* (1924) described a group of impulses that parallel the current definition of impulsivity. These, entitled *morbid impulses,* were "distinguished by violence, hastiness, skill, and regardlessness of the interests of others" (p. 149). Included in this group were the impulses to set fires, steal, have sex, commit suicide, and violate ethical boundaries. These morbid impulses were a component of a larger group he called *impulsive actions*, or actions that were performed "without proper deliberation" (p. 149).

One of Freud's followers, Otto Fenichel (1945), described what he termed an *impulse neurosis*, or difficulty deferring instantaneous actions or reactions as a result of visceral predispositions. This most closely mimics the modern definition of impulsivity, as he noted not only do impulse neuroses involve immediate actions, they are also caused by uncontrolled urges.

Impulsive aggression involves unplanned, immediate, violent responses to minimal provocation (Stanford, Greve, & Gerstle, 1997) and is considered reactive and emotional, accompanied by poor regulation of physiological arousal as well as loss of behavioral control (Barratt, 1991; Houston, Stanford, Villemarette-Pittman, Conklin, & Helfritz, 2003). Neuropsychological findings have demonstrated that impulsive aggression is correlated with executive dysfunction (Chambers, 2010), including a lack of impulse control (Stanford et al., 1997) and deficits in verbal strategic processing (Villemarette-Pittman, Stanford, & Greve, 2002).

Psychophysiological results show that impulsive aggressive individuals have reduced P3 amplitude (Barratt, Stanford, Kent, & Felthous, 1997; Mathias & Stanford, 1999) and increased P3 latency (Mathias & Stanford, 1999), demonstrating sensory and informational processing deficits. The P3 is a component of the event-related potential (ERP) that occurs approximately 300ms after the presentation of a low probability stimulus. Impulsive aggressors also have increased latency and reduced amplitude on the late positive potential, a measure of emotional processing (Conklin & Stanford, 2002). Individuals identified as impulsively aggressive also have a higher heart rate during challenging tasks than nonaggressive controls (Pitts, 1997).

Impulsive aggressors have problems with strategic processing and executive dysfunction (Stanford et al., 1997); they have a tendency to view situations with an aggressive tendency, as an immediate means to an end (Helfritz, 2006). In a positron emission tomography study using impulsive murderers compared to predatory murderers, impulsive murderers had lower prefrontal function during a continuous performance task (Raine, Meloy, Bihrle, Stoddard, LaCasse, & Buchsbaum, 1998). During an approach-motivated setting (but not a withdrawal-motivated setting), Harmon-Jones (2003b) found that relative left frontal cortical activity related to an experience of experimentally manipulated anger. A large amount of literature suggests that impulse control disorders related to an overreactive BAS (Gray, 1991; Revelle, 1997; Wallace, Newman, & Bachorowski, 1991) and thus more left frontal activity at a resting state.

Pilot Data

Assuming that the *motivational direction model* was the most likely theory for differences in frontal cortical asymmetry and that aggression and the BAS were related, 8-minute resting EEGs were recorded on $N = 24$ ($n = 12$ Impulsive Aggressors [IAs] and $n = 12$ nonaggressive controls) age- and gender-matched undergraduate participants. IAs were hypothesized to have increased left prefrontal activity and thus a tendency to utilize approach motivation (BAS) using aggression as a means to an end similar to previous research (Harmon-Jones & Sigelman, 2001; Hirono, Mega, Dinov, Mishkin, & Cummings, 2000), but the resting EEG showed differences in asymmetry activity in both the mid-frontal [$t(22) = 2.743$, $p = .005$] and lateral-frontal [$t(22) = 2.365$, $p = .01$] locations opposite of hypotheses—that is, IAs had lower asymmetry indices ($M_{\text{mid-frontal}} = -.0424$, $SD = .085$; $M_{\text{lateral-frontal}} = -.1158$, $SD = .228$) and thus more right activity (BIS) during rest than controls ($M_{\text{mid-frontal}} = .0630$, $SD = .098$; $M_{\text{lateral-frontal}} = .0508$, $SD = .114$; see Figure 1), even after controlling for anger using the Buss-Perry Aggression Questionnaire: Anger subscale and impulsivity using the Barratt Impulsiveness Scale-11 total score.

Because aggression and anger are related behaviors (Jensen-Campbell et al., 2007) and are both correlated with executive control functions such as behavioral inhibition, it was also hypothesized that higher left prefrontal cortical activity would be positively correlated to the total BAS score using Carver and White's (1994) BIS/BAS

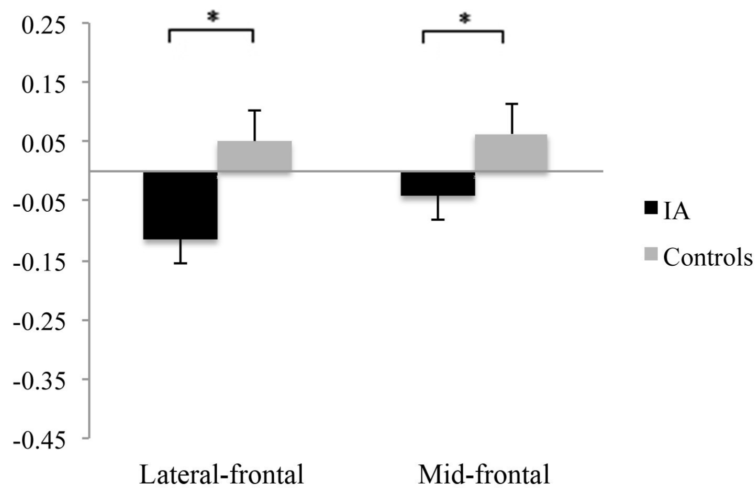

Figure 1. Resting asymmetry indices at midfrontal [$t(22) = 2.743$, $p = .005$] and lateral-frontal [$t(22) = 2.365$, $p = .01$] sites.

Scales. IAs and controls did not differ in three out of the four subscales [Behavioral Inhibition $t(22) = 1.264$, *ns*; BAS Reward $t(22) = .249$, *ns*; BAS Drive $t(22) = .586$, *ns*]. For BAS Fun-Seeking, controls scored higher than IAs [$t(22) = 2.288$, $p < .05$, $M_{\text{control}} = 8.43$, $SD = 2.138$; $M_{\text{IA}} = 6.22$, $SD = 2.438$] and thus reported more tendencies to engage the BAS.

Methodological Issues

An examination of the results of the pilot study yields little clarity. If the *motivational direction model* is correct and Carver and White's (1994) BIS/BAS Scales are valid, subscale and total BAS scores should have been related to increased left frontal activity. Conversely, BIS scores should have been related to increased right frontal activity at resting state. Results indicated the BIS/BAS Scales (Carver & White, 1994) might not be psychometrically valid in a psychopathological sample like IAs. However, because IAs actually had more right frontal activity, the *motivational direction model* postulates that IAs utilize the BIS more at a resting state than BAS. Indeed, BAS Fun-Seeking was positively correlated with the hemispheric index at mid-frontal (r = .432, p = .01) and lateral-frontal (r = .523, p = .01) sites, suggesting that controls engaged the BAS more than IAs, and higher BAS Fun-Seeking scores were related to more left frontal activity at a resting state (Lake & Stanford, 2011). The current study attempted to replicate the frontal cortical asymmetry results from this data as well as further elucidate the nature of frontal asymmetry and impulsive aggression.

Revised Reinforcement Sensitivity Theory

In 2000, Gray and McNaughton revised their motivational system theory using the results of animal research and conceived the revised Reinforcement Sensitivity Theory (rRST). The BAS is now believed to be sensitive to all appetitive stimuli, but remains largely unchanged (Gray & McNaughton, 2000; Keiser & Ross, 2011, McNaughton & Corr, 2004). The BIS is now believed to be responsible for the resolution of all goal conflicts regarding both threat and reward. Lastly, the FFS is now the fight-flight-freeze system (FFFS) and is responsive to *all* aversive stimuli—conditioned or unconditioned—similar to the punishment role of the BIS in the original RST. The FFFS gives rise to fearful feelings with responses aimed at reaching safety, and thus is most closely related to panic disorder and social phobia (Corr, 2008). The BAS is linked to Cluster B personality disorders (erratic behavior), whereas the BIS is linked to Cluster C personality disorders (anxious fearful behavior) (Ross, Keiser, Strong,

& Webb, 2013).The rRST proposes these three systems (BIS, BAS, and FFFS) underlie individual differences in sensitivity to punishment, reward, and motivation.

The main difference between the RST and rRST is the separation of the brain's response to fear (FFFS) and anxiety (BIS). Both the FFFS and BIS are involved in defensive responses, but the FFFS is activated when threat is to be avoided, whereas the BIS activates when a threatening situation is encountered (McNaughton & Corr, 2000,2004; Perkins, Kemp, & Corr, 2007). More simply, McNaughton and Corr (2004) used the terms *defensive avoidance* when the FFFS in engaged and *defensive approach* when the BIS is activated. The competition between reward sensitivity, the tendency to avoid aversive stimuli, and the interactions of these neural systems is referred to as the *joint subsystem hypothesis*, which is based on a passive mechanism of control (Carver, 2005; Kennis, Rademarker, & Geuze, 2013). That is, under certain circumstances, those with strong BAS-related personality traits are more apt to detect aversive stimuli easier and regard them as less threatening (Avila, 2001). If the stimulus remains negative, the BAS should engage the FFFS or BIS depending on whether or not the stimuli should be avoided or approached.

The question then arises: is disinhibition caused by a dysfunction in BAS or BIS? In goal-directed or rewarding behavior, those with an overactive BAS cannot easily interrupt approach behavior and thus cannot attenuate to punishing stimuli (Avila, 2001). Those with an underactive BIS have a lower sensitivity to punishment cues and an inability to process those regardless of appetitive motivation, and thus cannot appropriately extinguish aversive associations. Generally, in circumstances with frequent punishments or negative stimuli, those with an underactive BIS are less able to shift attention and cannot distinguish between aversive and appetitive stimuli (Avila, 2001). A weak or underactive BIS indicates inability to process emotional reactions to aversive cues as well (Avila, 2001; Gray & McNaughton, 2000).

Gray (1982) purposely hypothesized Extraversion (E) and Neuroticism (N) to be the main derivative factors resulting from BIS and BAS combinations. E and N are factors of punishment and reward sensitivities, with E reflecting the balance between these two sensitivities and N reflecting their joint strengths (Wallace et al., 1991; Carver, 2005). Because of this, many researchers have used the Eysenck Personality Questionnaire (EPQ; Eysenck & Eysenck, 1976) to measure BIS and BAS indirectly, with BIS negatively related to E but positively to N, and BAS positively related to both E and N (Corr, 2001; Kambouropoulos & Staiger, 2004; Patterson, Kosson, & Newman, 1987). Corr (2001) derived two dimensions from BIS and BAS using combinations of E, N, and Psychoticism (P): impulsivity, closely related to E, and anxiety, related to P (Gray, 1988; Pickering, Corr, & Gray, 1999). It is thought that impulsive individuals are more sensitive to rewarding stimuli, whereas low anxious individuals are less sensitive to aversive stimuli (Avila, 2001; Pickering, Diaz, & Gray, 1995).

Indeed, impulse-control disorders have consistently shown a large anxiety component. Anxiety is commonly found in impulse-control disorders (Black, Shaw, McCormick, Bayless, & Allen, 2012; Carli et al., 2013; Kashyap et al., 2012), with high anxiety eliciting distress and a need to fulfill the desired compulsion to alleviate the anxiety. IAs have a tendency to see all situations as threatening (Helfritz, 2006), thus they experience anxiety in both reinforcing and nonreinforcing situations. The anxiety they feel undermines their inhibition and subsequently increases their aggressive inclinations.

Neural Correlates

Many neural correlates have been found with rRST dimensions, although results occasionally overlap. BAS-related personality traits (activeness, enthusiasm, excitability, sociability; see Larsen & Buss, 2005) are positively related to ventral and dorsal striatum (Hahn et al., 2012). The ventral prefrontal cortex (PFC) is also related to positive stimuli (Burgdorf & Panksepp, 2006; Daffner et al., 2000; Davidson & Irwin, 1999; Depue & Collins, 1999). Shidara and Richmond (2002) suggested the anterior cingulate cortex is involved in reward expectancy when they found BAS-related traits were positively associated with positive stimuli and negatively correlated with negative stimuli. McNaughton and Corr (2004) showed participants with higher baseline levels of BAS activity could more easily activate the ventral tegmental area and PFC in response to positive stimuli. BIS-related personality traits (anxiety, guilt, inhibition of responses; see Larsen & Buss, 2005) are associated positively to amygdalar activity in response to negative stimuli, as well as avoidant behavior and punishment (Adolphs, Tranel, Damasio, & Damasio, 1994; Davis, 1992; LeDoux, 2000;2003). The BIS has also been associated both positively and negatively to cingulate activity in response to negative stimuli (Gray & McNaughton, 2000). The level of commonality between BIS, BAS, and related neural correlates demonstrate that these systems are not independent but instead have coinciding neuroanatomical locations (Pickering, 1997).

Manipulating Frontal Asymmetry

Studies using frontal resting electroencephalogram (EEG) activity either, 1) examine asymmetry as an individual difference related to traits or trait-like measures; 2) investigate asymmetry as an individual difference that can predict state-related emotional responses; 3) examine asymmetry as an individual difference related to psychopathology; or 4) investigate state-related asymmetry as a function of state changes in emotion (Coan & Allen, 2004). The first three types of studies focus on trait-like properties and assume frontal EEG activity is an inherent biological characteristic specific to the individual. The fourth presumes emotional state changes in asymmetry are observable and recordable. However, little research has examined asymmetry as a trait that can produce different indices depending on state emotional situations (Coan & Allen, 2004).

Although originally hypothesized to be orthogonal, research now shows there is overlap between the BIS and BAS (Pickering, 1997; Pickering, Corr, Powell, Kumari, Thorton, & Gray, 1997). For example, if a person has a highly reactive BAS and there are environmental rewards, the BAS should receive a strong input to activate the reward system. However if there are environmental punishments, the BIS too should receive strong input (Kennis et al., 2013; Pickering, 1997). This issue is why the rRST should be investigated in controlled, non-reinforcing conditions as well as laboratory manipulations.

Theories abound as to the importance of frontal asymmetry in regards to association with state or trait effects (Coan et al., 2006) but researchers agree emotional processing and reward motivation are the main factors. Harmon-Jones, Lueck, Fearn, and Harmon-Jones (2006) attempted to manipulate the salience of prejudice by using affective pictures while recording EEGs. Participants were asked to write an essay on why they believed racism was wrong, attempting to evoke the BAS. During prejudice-evoking pictures along with the expectation of approach-related behavior via essay writing, relative left frontal activity increased along with self-reported anger. Expanding this work, Harmon-Jones (2007) hypothesized that individuals higher on trait anger would show greater left frontal cortical activity in response to anger-evoking pictures. Using the BPAQ (Buss & Perry, 1992), individuals who scored highly on self-reported anger demonstrated greater relative left frontal cortical activity to pictures eliciting anger than pictures showing fear, disgust, positive, or neutral reactions (Harmon-Jones, 2007).

Frontal asymmetry is susceptible to manipulation through hand contractions as well (Harmon-Jones, 2006). Right-handed participants squeezed a rubber ball in one hand for two 45-second baseline periods before testing and then while watching a 2.5-minute computer paradigm in which they were asked to squeeze continuously. Participants then completed a survey of emotional reactions to the broadcast along with a measure of approach-related affect. Hand contractions produced cortical differences at mid-frontal regions, with right hand contractions related to greater relative left frontal activity. The researcher theorized that because self-reported approach affect was the only trait that correlated with frontal asymmetry (whereas sadness, guilt, happiness, and anger did not), the manipulation of brain activity via hand contractions influenced the affective experience (Harmon-Jones, 2006).

After effectively demonstrating frontal cortical manipulation, Peterson, Shackman, and Harmon-Jones (2008) used hand contractions and a behavior measure of aggression by the number of administered noise bursts after provocation during frontal asymmetry recordings. Greater left frontal cortical activity led to greater behavioral "aggression" and concluded these results demonstrated that not only does the prefrontal cortex inhibit aggressive behavior, greater activity of the left prefrontal cortical region was involved in causing situational, state aggression (Peterson et al., 2008).

Along with Harmon-Jones' (2007; Peterson et al., 2009) manipulations, Papousek, Reiser, Weber, Freudenthalar, and Schulter (2012) used an affective auditory paradigm in a college sample to induce negative and positive affective states. They demonstrated that participants with higher left frontal cortical resting states had shifts to the right during negative stimuli and left during positive stimuli, showing a flexible pattern of affective responding along with evidence to support the joint subsystem hypothesis (Kennis et al., 2013). Those with higher baseline right frontal cortical resting activity had no differences for each emotional condition, showing dysfunction in differentiating emotional responses. Papousek and colleagues' (2012) research establishes that frontal cortical asymmetry can be manipulated using affective stimuli.

Current Study

The current study attempted to replicate the frontal cortical asymmetry results from the pilot data as well as further elucidate the relationship between asymmetry and impulsive aggression. Because IAs have a tendency to see all situations as threatening (Helfritz, 2006), they experience anxiety in both reinforcing and nonreinforcing situations. The anxiety they feel undermines their inhibition and subsequently increases their aggressive inclinations. Thus, IAs should have increased right prefrontal activity similar to those with anxiety disorders (Fowles, 1988; Gray, 1982; Ross et al., 2013;

Quay, 1988) and previous research (Lake & Stanford, 2011), not comparable to exclusively anger or aggression research.

Hypotheses

IAs experience more anxiety and perceive most non-hostile situations as threatening (Helfritz, 2006; Houston et al., 2003), thus 1) IAs should have increased right prefrontal activity at both mid-frontal and lateral-frontal cortical regions.

The present study also attempted to clarify the nature of reinforcement tendencies and discriminate personality traits between IAs and controls. Thus, 2) IAs should have higher scores related to the Behavioral Inhibition System (BIS) as well as higher impulsivity and hostile attribution scores on self-report measures. Along with this, 3) higher BIS scores should be negatively related to Extraversion and positively related to Neuroticism (Corr, 2001; Kambouropoulos & Staiger, 2004; Patterson et al., 1987). Also, 4) higher BIS and irritability scores should predict right asymmetry. Conversely, because Neuroticism should increase arousal and focuses attention on reward (Corr, 2001), 5) sensitivity to reward (BAS) should be positively related to Neuroticism and Extroversion, and 6) higher BAS scores should predict left asymmetry.

Papousek and colleagues (2012) demonstrated that motivational flexibility and frontal lobe asymmetry are related. The current study utilized two affective picture presentations to demonstrate the difference in emotional control between IAs and controls. 7) While looking at withdrawal-related imagery, IAs should have an overactive BIS—and thus increased right activity at a resting state—due to a misappropriation of cognitive resources. When looking at approach-related imagery, IAs should have right activity similar to resting state. 8) Controls should be able to appropriately attend to all stimuli similar to previous research (Papousek et al., 2012) and thus approach motivation imagery should increase left frontal activity (more BAS) and withdrawal motivation imagery (more BIS) should increase right frontal activity. Lastly, regardless of whether or not a participant is impulsively aggressive, 9) the levels of BIS, BAS, hostility attribution, E, and N should predict asymmetry.

CHAPTER TWO

Research Design and Methods

Background and Neuropsychological Measures

Inclusion/Exclusion Criteria

Demographic and background questionnaire. This questionnaire solicited information about participants' age, year in school, ethnicity, first language, handedness, and medical history including previous major head injuries and current use of psychoactive medications. Due to males having a higher tendency to display impulsivity in violent ways (Boyd, 2008; Coccaro, Berman, & Kavoussi, 1997; McElroy, Soutullo, Beckman, Taylor, & Keck, 1998) and handedness affecting asymmetry (Harmon-Jones, 2006), only right-handed males were included in the current study.

Participant Selection

Individuals completed initial measures to determine eligibility for participation in psychophysiological measures. The Impulsive Aggression Quick Screen (IA-QS: Stanford, Greve, & Dickens, 1995) was the determinant for categorization into groups. To be classified as impulsively aggressive, an individual met four criteria: 1) Identified several episodes of impulsive aggression with loss of behavioral control in the past six months; 2) The aggressive act was disproportionate to the provocation or preceding event; 3) At least two impulsive aggressive acts occurred during the previous 30 days; and 4) A score 8 or higher on the Irritability subscale of the Buss-Durkee Hostility

Inventory. Age-matched controls reported no episodes of aggression with loss of behavioral control in the previous six months. Along with an absence of an aggressive history, all controls had a score of 3 or less on the Irritability subscale.

Aggression and Impulsivity Measures

Impulsive Aggression Quick Screen. The IA-QS (Stanford et al., 1995) is used to classify an individual as predominately impulsively aggressive. This measure uses DSM-IV-TR criteria for Intermittent Explosive Disorder combined with the Irritability subscale from the Buss-Durkee Hostility Inventory (BDHI; Buss & Durkee, 1957). The IA-QS was designed to assess a person's aggressive behavior over the previous six months.

Lifetime History of Aggression Questionnaire. The Lifetime History of Aggression Questionnaire (LHA; Coccaro, et al., 1997) assessed the extent of aggressive history of the participant. Participants were asked to rate the frequency of eleven antisocial behaviors since the age of thirteen such as "How many times would you say you got into physical fights with other people" to produce three subscales: aggression, self-directed aggression, and antisocial behavior. A total score indicates the level of history with a higher score signifying a more extensive aggressive history.

Barratt Impulsiveness Scale. The BIS-11 (Patton, Stanford, & Barratt, 1995) is a self-report measure that assesses general impulsiveness and produces three second-order subscales (attentional, motor, and non-planning). Items such as "I do things without thinking" and "I am self controlled" are scored on a four-point scale with *1* =

Rarely/Never and *4 = Almost Always/Always*. A total impulsiveness score is acquired by summing the 30 items with higher total scores representing more general impulsiveness.

Buss-Perry Aggression Questionnaire. The BPAQ (Buss & Perry, 1992) is a 29-item self-report measure that measures trait aggression. Participants answered questions like "Once in a while I can't control the urge to strike another person" on a five-point scale with *1 = Extremely uncharacteristic of me* and *5 = Extremely characteristic of me*, with four subscales measuring individual components of aggression: physical aggression, verbal aggression, anger, and hostility.

Conflict Situation Vignettes. The Conflict Situation Vignettes (Tremblay & Belchevsk, 2004) consist of 24 items in which participants read different vignettes and answer the degree to which the situation makes them feel angry on a *0 = Not angry at all* to *10 = Extremely angry*. The vignettes depict various daily situations where a person or group of individuals behaves in unintentionally, ambiguously, or intentionally provocative manners, such as "You are walking across a busy intersection, and it is clear you have the right-of-way. A man in a car, who is trying to turn right, almost hits you. He brakes in the middle of the street and yells out at you, 'You stupid idiot.' He then pulls over in a parking spot a few meters away."

Substance Use Measures

Alcohol Use Disorders Identification Test. The AUDIT (Babor, de la Fuente, Saunders, & Grant, 1989) is a short, 10-item questionnaire intended to assess quantitative drinking behavior, frequency of consumption, and alcohol-related problems. The first eight items, such as “How often do you have a drink containing alcohol?” are rated as: *0 = Never, 1 = Monthly or Less, 2 = Two to Four Times a Month, 3 = Two or Three Times a Week, and 4 = Four or More Times a Week*. The last two questions, “Have you or someone else been injured as a result of your drinking” and “Has a relative, friend, doctor, or other health worker been concerned about your drinking or suggest you cut down?” are rated as: *0 = No, 1 = Yes but Not in the Last Year,* and *2 = Yes During the Last Year*. A total score is calculated by summing the responses, with higher scores indicating more alcohol usage.

Drug Abuse Screening Test. The DAST-20 (Skinner, 1982) is a short survey to measure the presence and severity of drug use in the previous year, intended for use in clinical and research settings. This 20-item *Yes/No* test with items like “Have you abused prescription drugs?” can be summed by counting all *Yes* responses, with higher scores indicating more drug-related problems.

Reinforcement Sensitivity Measures

Eysenck Personality Questionnaire-Revised. Combinations of the subscales of the Eysenck Personality Questionnaire-Revised (EPQ-R; Eysenck & Eysenck, 1976) have been used to measure behavioral inhibition and activation based on Gray’s (1981) hypothesis that extraversion and neuroticism are related to the biological systems that underlie the motivations (Torrubia et al., 2008). The EPQ-R short scale version is comprised of 48 *Yes/No* items and consists of three subscales: Extraversion (E), Neuroticism (N), and Psychoticism (P). High scores on Extraversion are characterized by a need of external stimulation, or a person who is outgoing and talkative. High scores on

Neuroticism are indicative of high levels of negative affect, such as depression, anxiety, or emotional instability. High scores on Psychoticism are indicative of aggression, the susceptibility to have a psychotic episode, recklessness, or hostility.

Behavioral Inhibition Scale/Behavioral Activation Scale. The BIS/BAS Scale (Carver & White, 1994) measure individuals' tendency to use either the behavioral approach system (BAS) or the behavioral inhibition system (BIS). The BAS Scale measures energetic pursuit of rewards and positive emotional reactivity to rewarding events. The BIS Scale measures self-perceived proneness to anxiety in the presence of threat cues. The BIS/BAS Scale is comprised of four subscale scores (BAS Drive, BAS Fun Seeking, BAS Reward Responsiveness, and BIS) with 24 self-report items rating agreement on a 4-point scale, including items like "I have very few fears compared to my friends" and "When I want something I usually go all-out to get it."

Sensitivity to Punishment and Sensitivity to Reward Questionnaire. The SPSRQ (Torrubia, Avila, Molto, & Caseras, 2001) is a 48-item questionnaire comprised of two scales: Sensitivity to Punishment and Sensitivity to Reward. The Sensitivity to Punishment scale is intended to measure BIS activity by asking questions related to behavioral inhibition or worry produced by the threat of punishment with questions like "Are you afraid of new or unexpected situations?" and "Whenever possible, do you avoid demonstrating your skills for fear of being embarrassed?" The Sensitivity to Reward scale aims to measure BAS activity with questions such as "Do you spend a lot of your time on obtaining a good image?" and "As a child, did you do a lot of things to get people's approval?" All questions are *Yes/No* answers with scores computed by summing the total number of *Yes* answers for each scale.

Physiological Measurement

Resting EEG

Physiological recordings were measured in the late afternoon or early evening (3:00PM-6:00PM) to control for diurnal scalp variations (Peterson & Harmon-Jones, 2009). After giving informed consent, participants' scalps were prepared with rubbing alcohol and a slightly abrasive gel (NuPrep) to increase scalp conduction. Heads were fitted with a Neuroscan Quick-Cap with 64 tin electrodes (International 10-20 system) with standard and intermediate positions. To allow for removal of data contaminated by the eye and facilitate differentiation of artifact, four electrodes around the participant's eye recorded blinks and movement. One electrode on each mastoid provided data for referencing as suggested by previous literature (Davidson, Jackson, & Kalin, 2000). Impedance for each electrode was maintained at less than 5 kΩ. EEGs were digitized at a sampling rate of 1,000 samples per second and amplified by SYNAMPS^2 amplifiers (Compumedics Neuroscan, Charlotte, NC). A bandpass filter was set at 0.1 Hz to 35 Hz to separate out unnecessary frequencies. Participants sat in a padded chair in a radio frequency isolated anechoic chamber during all EEG paradigms. The resting EEG lasted for eight minutes with one-minute blocks of eyes open (O) or closed (C) in one of two counterbalanced orders (OCCOCOOC or COOCOCCO) with a 15-second buffer between blocks for participants to switch conditions.

Emotional EEG

In the current study, Papousek and colleague's (2012) auditory paradigm was modified to show differences in emotional responses between controls and IAs. Each emotional EEG presentation consisted of 35 images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Previous studies used emotion-eliciting films to show differences in frontal cortical asymmetry (Lopez-Duran, Nusslock, George, & Kovacs, 2012), but affective pictures should control nuisance variation due to their standardized ratings. The two counterbalanced trials lasted approximately five minutes long each, consisting of equally arousing withdrawal ($M_{valance} = 3.69$, $SD = 0.93$; $M_{arousal} = 5.88$, $SD = 0.77$) or approach ($M_{valence} = 7.12$, $SD = 0.50$; $M_{arousal} = 5.52$, $SD = 0.92$) motivated pictures chosen from Lang and colleague's (2008) evocative ratings. Pictures eliciting withdrawal motivation included aggressive animals, mutilation, or threat (see Appendix A). Pictures eliciting approach motivation included appetitive scenes, such as Disneyland, an astronaut in space, or a romantic embrace (see Appendix B). During the viewing of the emotional picture presentations, two separate EEGs were recorded with a 2-minute resting period between the two affective trials.

CHAPTER THREE

Results

Data Reduction and Analysis

For each individual EEG, eyeblinks were spatially filtered using an average eye blink correction for electrodes affected by the blinks. Data with excessive artifact due to participant movement were rejected and not included in data reduction. Both mid-frontal (F3 and F4 electrodes) and lateral-frontal (F7 and F8 electrodes) regions were of particular interest, similar to previous research (Harmon-Jones, 2006; Lake & Stanford, 2011). A fast Fourier transformation (FFT) separated all artifact-free data into specific wavelengths (e.g. alpha, delta, etc.) similar to previous research (e.g. Coan & Allen, 2003; Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004) with a Hamming window of 1 second and a 50% overlap. Bonferroni corrections controlled Type I error inflation per family.

Average alpha power at each site was natural log transformed. Then, hemispheric asymmetry indices were calculated by region of interest (ln[right] – ln[left], producing a hemispheric index similar to previous research (e.g. Coan & Allen, 2003; Harmon-Jones et al., 2004). Because alpha activity correlates inversely with cortical activity (Lindsley & Wicke, 1974), higher asymmetry index scores indicate increased left cortical activity.

Statistical Results

From the $N = 34$ subjects who participated, three participants classified as IA and one participant classified as a control were not included in the analysis. Two participants reported lack of physical aggression during the Lifetime History of Aggression Questionnaire interview, one participant was left-handed, and one participant disclosed a head injury during conversation that was not reported on the prescreen survey. A total of $N = 30$ participants comprised the final sample ($n = 15$ IAs). All participants were age-matched [$t(28) = -.769$, *ns*].

Hypothesis 1

IAs showed increased right activity compared to controls during rest at lateral-frontal sites [$t(28) = 2.470$, $p = .02$; $M_{IA} = -.103$, $SD = .421$, $M_{control} = .056$, $SD = .092$, Cohen's $d = .226$], and marginally significantly at mid-frontal sites [$t(28) = 2.205$, $p = .03$], see Figure 2. This replicates previous research that IAs have the propensity to have the BIS activated at a resting state compared to controls.

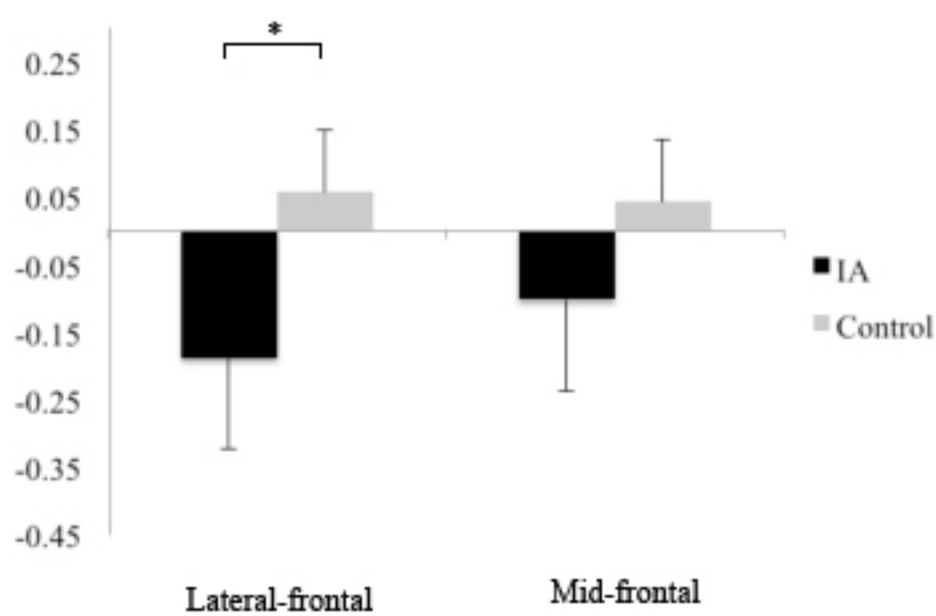

Figure 2. Resting activity difference score means; lateral-frontal $t(28) = 2.470$, $p = .02$; mid-frontal $t(28) = 2.205$, *ns*.

Previous research identified anger as influencing frontal asymmetry. An ANCOVA with BPAQ Anger as the covariate still demonstrated differences between IAs and controls' frontal asymmetry indices at lateral frontal sites, $F(2, 27) = 5.507$ $p = .01$, see Figure 3.

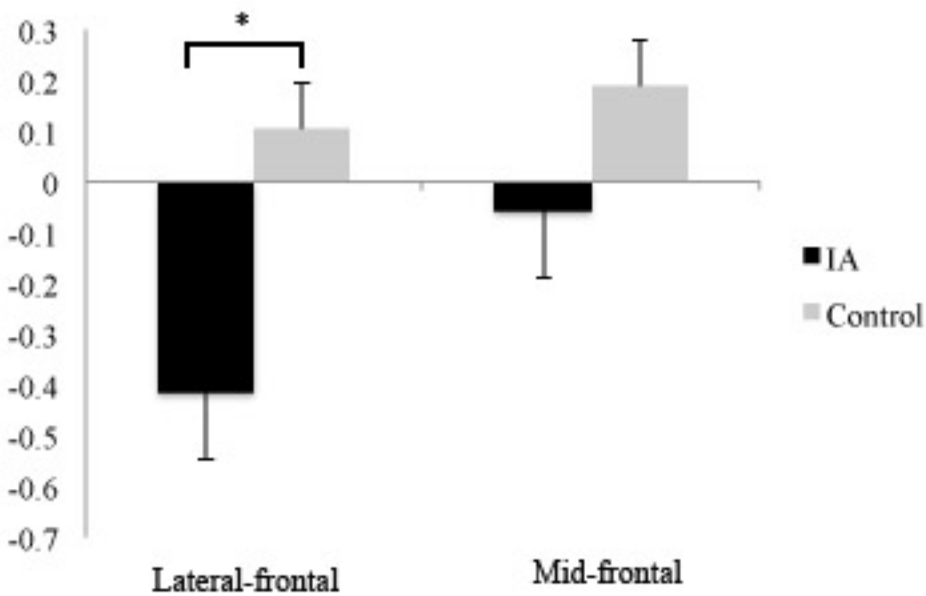

Figure 3. Resting activity difference score means with BPAQ Anger as a covariate; lateral-frontal $F(2, 27) = 5.507$, $p = .01$; mid-frontal $F(2, 27) = 2.273$, *ns*.

Because lateral-frontal sites were statistically significant and mid-frontal sites only marginally significant after controlling for Type I error ($p = .03$), further results include only lateral-frontal sites in asymmetry indices.

Hypothesis 2

As predicted, IAs scored higher on most self-report measures of impulsivity, anger, and irritability compared to controls. IAs reported more history of aggression [LHA Aggression: $t(28) = -4.195$, $p = .000$, $d = 1.53$; LHA Consequences/Antisocial:

t(28) = -3.360, *p* = .002, *d* = 1.23; LHA Total: *t*(28) = -4.772, *p* = .000, *d* = 1.743], attentional impulsivity [BIS-11 Attention: *t*(28) = -3.692, *p* = .000, *d* = 1.347], physical aggression [BPAQ Physical: *t*(19.023) = -6.819, *p* = .000, *d* = 2.491], verbal aggression [BPAQ Verbal: *t*(21.837) = -2.895, *p* = .000, *d* = 1.055], anger [BPAQ Anger: *t*(15.930) = -8.602, *p* = .000, *d* = 3.141], hostility [BPAQ Hostility: *t*(28) = -3.610, *p* = .001, *d* = 1.318], neuroticism [EPQ-R N: *t*(28) = -5.263, *p* = .000, *d* = 1.923], tendency to prefer BIS [BIS/BAS BIS: *t*(28) = -3.093, *p* = .004, *d* = 1.131; SPSRQ SP: *t*(28) = -4.047, *p* = .000, *d* = 1.477], drug use [DAST-20: *t*(14.639) = -3.118, *p* = .007, *d* = 1.390], and anger towards intentional [CSV Intentional: *t*(28) = -3.745, *p* = .001, *d* = 1.367] as well as ambiguous conflict situations [CSV Ambiguous: *t*(28) = -2.797, *p* = .009, *d* = 1.021] (see Table 2 for full means and standard deviations).

A covariate analysis indicated that even after controlling for increased self-reported drug use in IAs, IAs and controls still showed differences in resting frontal cortical asymmetry at lateral-frontal sites, *F*(2, 27) = 4.946, *p* = .015.

Hypothesis 3

BIS scores were hypothesized to be negatively related to Extraversion and positively related to Neuroticism using the EPQ-R (Eysenck & Eysenck, 1975) similar to previous research (Corr, 2001; Kambouropoulos & Staiger, 2004; Patterson, Kosson, & Newman, 1987). Although scores on Carver and White's (1994) BIS scale did not significantly correlate with Extraversion (*r* = -.152, *ns*), using Torrubia and colleagues' (2001) SPSRQ SP, there was a significant negative correlation between SP and Extraversion (*r* = -.542, *p* = .003). Scores on both Carver and White's (1994) and

Table 2
Means and Standard Deviations of Self-Report Measures

Measure	α	IAs *M*	IAs *SD*	Controls *M*	Controls *SD*	*t*	*p*
LHA-Revised	.82						
Aggression		11.40	4.67	4.87	3.82	-4.195	.000
Self-Directed Aggression		.80	1.42	.07	.26	-1.962	*ns*
Consequences/Antisocial		2.00	1.41	.47	1.06	-3.360	.002
Total		14.07	5.42	5.40	4.49	-4.772	.000
BIS-11	.85						
Attention		20.60	4.31	15.67	2.87	-3.692	.000
Motor		23.13	3.54	23.40	4.47	-1.223	*ns*
Nonplanning		24.80	5.32	23.40	4.47	-.780	*ns*
Total		68.53	5.42	60.40	8.99	-2.237	.*ns*
BPAQ	.79						
Physical		24.40	5.88	13.13	2.53	-6.819	.000
Verbal		16.33	4.99	12.07	2.76	-2.895	.008
Anger		21.40	5.14	9.60	1.35	-8.602	.000
Hostility		25.00	6.96	16.27	6.26	-3.610	.001
Total		87.13	17.10	51.07	9.47	-7.148	.000
EPQ-R	.82						
P		2.93	1.62	2.60	1.72	-.545	*ns*
E		7.40	4.21	9.00	2.59	1.255	*ns*
N		8.07	3.26	2.60	2.35	-5.263	.000
BIS/BAS	.86						
BIS		20.80	3.12	17.33	3.02	-3.093	.004
Reward		16.40	2.56	16.27	3.73	-.114	*ns*
Drive		10.67	2.06	11.20	2.93	.576	*ns*
Fun-Seeking		12.13	2.32	11.07	3.67	-.961	*ns*
SPSRQ	.93						
SP		14.53	4.14	8.60	3.89	-4.047	.000
SR		13.07	4.30	12.33	3.75	-.498	*ns*
DAST-20	.87	6.73	5.41	2.33	3.75	-3.118	.007
AUDIT	.86	4.73	3.90	2.33	3.44	-1.788	*ns*
CSV	.83						
Intentional		7.85	1.66	5.28	2.08	-3.745	.001
Ambiguous		6.45	1.89	4.48	1.95	-2.797	.009
Unintentional		4.35	2.19	2.83	1.57	-2.197	.*ns*

Note. Scales are as follows: Buss-Durkee Hostility Inventory (BDHI: Buss & Durkee, 1957); Lifetime History of Aggression (LHA: Coccaro et al., 1997); Barratt Impulsiveness Scale (BIS-11: Patton et al., 1995); Buss-Perry Aggression Questionnaire (BPAQ: Buss & Berry, 1992); Eysenck Personality Questionnaire-Revised (EPQ-R: Eysenck & Eysenck, 1975); Behavioral Inhibition/Activation Scale (BIS/BAS: Carver & White, 1994); Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ: Torrubia et al., 2001); Drug Abuse Screening Test (DAST-20: Skinner, 1982); Alcohol Use Disorders Identification Test (AUDIT: Babor et al., 1989); Conflict Situation Vignettes (CSV: Tremblay & Belchevsk, 2004).

Torrubia et al.'s (2001) scales of BIS tendencies showed positive correlations with Neuroticism (BIS: $r = .762$, $p = .000$; SPSRQ SP: $r = .700$, $p = .000$).

Hypothesis 4

Since the BIS is related to right frontal asymmetry, higher BIS and irritability scores should predict right asymmetry. Contrary to hypotheses, neither the BIS subscale (Carver & White, 1994), SPSRQ's SP (Torrubia et al., 2001), nor irritability (Tremblay & Belchevsk, 2004) predicted right asymmetry [$F(3, 26) = 1.728$, *ns,* $R^2 = .166$].

Hypothesis 5

Because Neuroticism and Extraversion reflect the degree of sensitivity to reward, scores on EPQ-R's N and E subscales should be positively related with all self-report measures of the BAS. Contrary to hypotheses, no significant correlations appeared with any of the subscales with Neuroticism (BAS Reward: $r = .269$, *ns*; BAS Drive: $r = .048$, *ns*; BAS Fun-Seeking: $r = .285$, *ns*; SPSRQ SR: $r = .116$, *ns*). Only the BAS Fun-Seeking subscale correlated with Extraversion ($r = .378$, $p = .039$); no other subscales showing any other significant relationship (BAS Reward: $r = .255$, *ns*; BAS Drive: $r = .345$, *ns*; SPSRQ SR: $r = .235$, *ns*).

Hypothesis 6

Since the BAS is related to left frontal asymmetry, higher BAS scores should predict left asymmetry. Contrary to hypotheses, neither the BAS subscales (Reward, Drive, and Fun-Seeking; Carver & White, 1994) nor SPSRQ's SR (Torrubia et al., 2001) predicted right asymmetry [$F(3, 26) = 1.242$, *ns*, $R^2 = .166$].

Hypotheses 7 and 8

The seventh hypothesis anticipated IAs have an overactive BIS while watching withdrawal-related stimuli, thus they should have increased right activity due to an inability to appropriate cognitive resources. Similarly, the eighth hypothesis expected that controls should attend to emotional stimuli and thus have increased left frontal activity during approach motivation imagery and increased right frontal activity during withdrawal imagery. Because it is unclear how quickly frontal asymmetry changes, the first half of all affective EEGs was omitted. The following results utilize the last three minutes of the emotional imagery EEGs, assuming that the two-minute break between the two emotional paradigms plus the first three minutes of any manipulation EEG was sufficient enough time for the frontal lobe to return to its original resting state.

Using a within-subjects 2 (Group: IA, control) X 3 (Task: resting, withdrawal imagery, approach imagery) factorial design, there was a significant Group X Task interaction, $F(2, 14) = 3.818$, $p = .028$, indicating that controls and IAs had different asymmetry indices at more than two paradigms (see Figure 4).

Examining the means of both groups in each of the affective picture tasks, controls are able to attend to emotional stimuli by engaging the BIS during withdrawal imagery and engaging the BAS during approach imagery. Conversely, IAs had similar asymmetry indices across all tasks and thus had trouble appropriating cognitive resources to emotional cues.

Hypothesis 9

Lastly, regardless of whether or not a participant is impulsively aggressive or not, the levels of BIS, BAS, hostility attribution, E, and N should predict asymmetry level. Using Carver and White's (1994) BIS and BAS scores; Torrubia et al.'s (2001) SPSRQ

SP and SR scales; Eysenck's (1975) E, N, and P scales; and Tremblay and Belchevsk's (2004) hostile attribution, no significant prediction resulted [$F(9, 20) = 1.627$, *ns*].

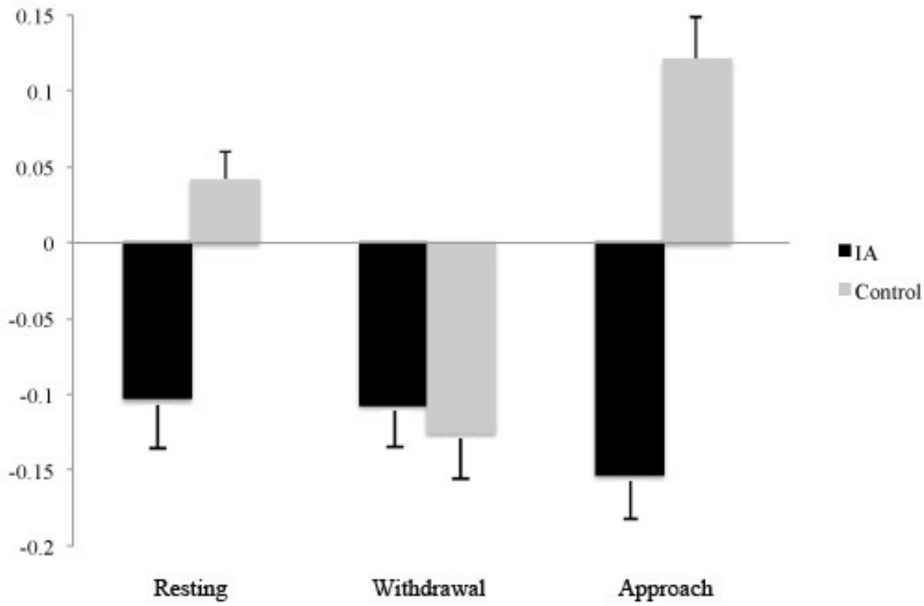

Figure 4. Comparison of within-groups asymmetry indices during a resting state, approach imagery, and withdrawal imagery. IAs had similar asymmetry indices throughout all conditions, whereas controls attenuated to withdrawal stimuli with increased right activity compared to their resting state [$F(2, 14) = 3.818$, $p = .028$].

CHAPTER FOUR

Discussion and Conclusions

As hypothesized based on pilot data, IAs had increased right frontal cortical activity compared to controls, showing more BIS activity during a resting state. This result sustained even after covarying impulsivity and anger separately, suggesting trait anger and impulsivity were not the underlying personality traits causing this asymmetry. When examining the emotional manipulations, IAs had similar asymmetry indices across all conditions and thus were unable to utilize the appropriate motivational system from emotional cues. Because controls were able to engage the BIS during withdrawal-related stimuli, one of three conclusions is likely: IAs have an overactive BIS and normal BAS, an overactive BIS with underactive BAS, or a normal BIS and underactive BAS. Given that research shows an overactive BIS underlies the temperamental quality of inhibition and pathological anxiety (Oosterlaan, 2001), this study lends evidence that the BIS is likely overactive in IAs. Due to the computation of asymmetry indices instead of comparing a baseline level of activity to activation of both BIS and BAS during the affective picture tasks, it is unclear if IAs have an underactive BAS along with an overactive BIS, or if the BIS overtakes a normal BAS.

Because impulsive aggression is a problem with emotional regulation (Stanford et al., 1997), the current study lends evidence to IAs having dysfunction in emotional processing. This result also replicated Papousek and colleagues' (2012) research that those who have increased right frontal activity at a resting state cannot differentiate emotional responding. The rRST is theorized to be a top-down process in which stimuli must be classified by the BAS as rewarding (engaging the BAS) or aversive (engaging the BIS or FFFS depending on the nature of the stimuli) and then behavior will engage appropriately (see Avila, 2001). In IAs, the BIS is already engaged at a resting state, thus is overactive and the reason for why IAs cannot control their aggressive outbursts in perceived aversive situations—because they see non-hostile situations as threatening. This also may be why IAs could not appropriately perceive emotional stimuli as well: an overactive BIS along with high anxiety and a lack of emotional regulation. High-anxious individuals are more sensitive to aversive stimuli (Avila, 2001; Pickering et al., 1995), thus IAs probably have a dysfunctional BIS. This study lends credence to Harmon-Jones's (2003b) motivational direction model, which lines up with Gray and McNaughton's (2000) rRST.

A fourth dimension of the rRST recently emerged among the self-report literature (Kennis et al., 2013). *Constraint* is hypothesized to be superordinate to the BIS/BAS/FFFS and acts to inhibit impulses and override the tendency not to act (Carver, 2005; Corr, 2011). Complementary to the BIS, constraint is involved in attention management and inhibitory control (Corr, 2011). Constraint interacts with the BIS to avoid behavioral confusion, thus maybe the overactive BIS seen in IAs is actually a constraint/BIS problem rather than a BIS/BAS problem. Recent theories hypothesize constraint and BIS to be controlled processing, essentially in charge of the BAS and FFFS's automatic processing (Corr, 2013). Clinically, constraint broadly defines the opposite of disinhibition; that is, behaving in an overcontrolled manner (Clark & Watson, 2008). The "disinhibition versus constraint" connection has shown to be associated with aggression and substance abuse, along with other externalizing-related behaviors

(Latzman, Vaidya, Clark, & Watson, 2011). Although constraint has been used as a construct in the clinical literature, its use has been a relatively new hypothesized addition to the rRST, thus limited psychophysiological research has been done and consequently little is known.

A few hypotheses focused on using self-report measures to predict resting state frontal cortical asymmetry, none of which were valid. This is probably because most multiple regression models require a larger sample size due to large disparity in predicting variables between participants (Kelley & Maxwell, 2003). The power analysis performed before the experiment indicated a sample size of $n = 15$ for each group would be sufficient enough to show differences in physiology, but a separate analysis was not performed for the prediction models. Future studies that employ regression models should utilize a larger sample size.

Conclusions

In line with the revised Reinforcement Sensitivity Theory, IAs showed more right activity and thus engaged the BIS at rest compared to controls. Although controls could attend to emotional stimuli, IAs were unable to engage the appropriate motivational systems providing evidence that impulsive aggression is the result of anxiety (Perkins et al., 2007; Stanford et al., 1997) due to misappropriation of attentional and emotional resources similar to the emotional processing problems seen in previous research (Conklin & Stanford, 2002). This study lends evidence towards resting and manipulated frontal lobe asymmetry as an inherent marker for susceptibility to psychopathology. More right activity in IAs means that those with an aggressive impulse control problem cannot appropriate cognitive resources to emotional stimuli and thus act out aggressively due to anxiety and seeing nonthreatening situations as threatening. This line of research showed that IAs have dysfunction in emotional processing and atypical biological systems, further demonstrating that therapies focusing on helping impulsive aggressors change the way they process emotional information are the best way to reduce symptomology.

APPENDICES

APPENDIX A

Table A.1: IAPS Photographs and Standardized Ratings for Withdrawal Paradigm

Description	IAPS Number	Valence	Arousal	Dominance
Snake	1019	4.67 (1.63)	5.34 (1.76)	4.53 (2.03)
Snake	1022	4.48 (1.62)	5.83 (1.86)	4.13 (1.90)
Snake	1050	3.90 (2.28)	6.84 (1.55)	3.14 (1.78)
Snake	1051	4.53 (1.61)	5.79 (1.69)	4.49 (2.11)
Snake	1052	4.35 (1.56)	5.92 (2.20)	4.46 (2.23)
Snake	1110	4.07 (2.03)	6.02 (2.07)	4.27 (2.38)
Snake	1113	4.37 (1.72)	5.73 (2.07)	4.58 (2.14)
Snake	1120	4.73 (1.75)	6.60 (1.38)	4.67 (1.10
Spider	1201	4.27 (1.73)	5.75 (1.99)	4.94 (2.10)
Pitbull	1300	4.06 (1.54)	6.90 (1.59)	3.67 (1.88)
Dog	1302	4.38 (1.64)	5.89 (1.79)	4.63 (2.33)
Bear	1321	4.94 (1.71)	6.34 (1.94)	3.96 (2.28)
Shark	1931	4.51 (2.35)	6.88 (1.77)	3.94 (2.66)
Angry Face	2120	3.65 (2.05)	4.93 (2.46)	5.30 (2.22)
Policeman	2681	3.80 (1.42)	5.09 (2.25)	4.24 (2.70)
Policeman	2682	3.98 (1.57)	4.43 (2.33)	4.72 (2.37)
Mutilation	3000	2.21 (1.86)	6.92 (2.44)	3.41 (2.80)
Mutilation	3030	2.31 (1.87)	6.39 (2.26)	3.97 (2.59)
Mutilation	3060	1.94 (.39)	6.89 (2.08)	3.07 (1.96)
Mutilation	3150	2.59 (1.56)	6.10 (2.29)	3.54 (2.03)
Baby Tumor	3170	1.77 (1.31)	6.79 (1.93)	3.23 (2.04)
Tornado	5970	4.31 (1.64)	4.65 (2.61)	3.79 (2.54)
Aimed Gun	6190	4.52 (1.79)	4.83 (1.81)	4.54 (2.31)
Aimed Gun	6230	2.73 (1.48)	7.10 (2.07)	2.34 (2.13)
Aimed Gun	6243	2.80 (1.61)	5.60 (2.34)	3.91 (2.44)
Gun	6250_1	3.38 (1.97)	6.53 (2.07)	6.02 (1.98)
Knife	6300	3.30 (1.67)	6.37 (1.73)	3.41 (2.08)
Gang	6821	2.96 (1.93)	5.93 (2.10)	3.95 (2.42)
Boxer	8230	4.17 (1.99)	5.75 (2.16)	4.29 (2.58)
Biker on Fire	8480	4.50 (2.09)	5.83 (2.16)	4.31 (2.17)
Stick Through Lip	9042	3.93 (1.98)	5.13 (2.99)	5.04 (2.11)
Mob	9402	4.67 (2.06)	4.94 (2.24)	4.87 (2.12)
Sliced Hand	9405	2.09 (1.27)	5.31 (2.38)	3.96 (2.48)
Nazi	9800	2.48 (1.85)	5.96 (2.66)	5.54 (2.43)
KKK Rally	9810	2.25 (1.84)	6.74 (2.33)	3.94 (2.49)
Total		*3.69 (0.93)*	*5.88 (0.77)*	*4.20 (0.74)*

APPENDIX B

Table B.1: IAPS Photographs and Standardized Ratings for Approach Paradigm

Description	IAPS Number	Valence	Arousal	Dominance
Dog	1500	6.77 (1.95)	4.08 (1.58)	6.33 (1.72)
Pony	1590	6.77 (1.50)	4.87 (2.01)	5.65 (1.91)
Horse	1600	6.95 (1.59)	4.08 (2.02)	7.02 (2.02)
Puppies	1710	8.02 (1.21)	5.53 (2.07)	6.61 (1.86)
Baby Jaguar	1722	6.85 (1.55)	4.65 (2.07)	6.47 (1.82)
Monkeys	1811	7.22 (1.59)	5.05 (1.84)	5.91 (2.06)
Mickey Mouse	1999	7.17 (1.40)	4.52 (2.31)	6.42 (1.90)
Woman	2030	7.51 (1.68)	6.24 (1.83)	5.93 (1.72)
Baby	2057	7.16 (1.31)	4.32 (1.98)	6.70 (1.90)
Father	2160	6.87 (1.87)	5.31 (2.10)	6.36 (1.98)
Kids in Pool	2216	7.12 (1.41)	5.08 (2.14)	6.50 (1.90)
Child at Beach	2655	6.62 (1.47)	4.15 (1.99)	6.09 (2.21)
Attractive Female	4150	7.80 (1.36)	6.41 (2.18)	6.24 (1.73)
Attractive Female	4250	8.39 (0.93)	7.02 (2.02)	6.06 (2.03)
Girl with Cycle	4275	7.51 (1.08)	6.00 (2.16)	6.68 (2.09)
Volleyball Man	4533	5.42 (1.92)	4.12 (2.37)	5.85 (1.76)
Romance	4599	7.02 (1.28)	5.73 (1.93)	6.54 (1.73)
Romance	4601	6.96 (1.10)	5.25 (2.02)	6.48 (1.59)
Romance	4608	7.55 (1.28)	6.84 (1.63)	6.37 (1.73)
Romance	4641	7.16 (1.47)	5.53 (2.10)	6.54 (1.62)
Astronaut	5470	7.38 (1.82)	6.44 (2.40)	4.75 (2.57)
Fireworks	5480	7.37 (1.80)	5.55 (2.37)	5.88 (2.06)
Skydivers	5621	7.28 (1.22)	6.96 (1.72)	5.94 (2.29)
Windsurfing	5623	7.12 (1.29)	5.56 (2.30)	6.52 (1.59)
Mountains	5628	6.42 (1.82)	5.54 (2.13)	6.15 (2.35)
Mountain	5660	7.16 (1.66)	5.25 (2.51)	4.84 (2.39)
Nature	5780	7.35 (1.46)	4.13 (2.60)	6.04 (2.31)
Earth	5890	6.60 (1.95)	5.17 (2.37)	3.83 (2.76)
Fireworks	5910	7.41 (1.20)	5.37 (2.43)	5.33 (1.97)
Disney	7502	7.30 (1.44)	5.74 (1.97)	6.69 (2.07)
Skyline	7570	6.60 (1.87)	6.27 (1.98)	5.38 (2.35)
Skier	8034	6.90 (1.41)	6.20 (2.24)	6.03 (1.96)
Skydiving	8185	7.32 (1.58)	7.06 (2.09)	5.59 (2.19)
Rafters	8400	7.43 (1.40)	7.00 (1.56)	4.60 (2.29)
Rollercoaster	8490	6.85 (2.36)	6.25 (1.96)	5.33 (2.40)
Total		*7.12 (0.50)*	*5.52 (0.92)*	*5.99 (0.69)*

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