The Effect of Frontal Lobe Stress on Gambling Task Performance: Implications for Understanding Addictive Behavior

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Psychology

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8/10/2010

Blacksburg, VA

Keywords: Decision Making, Substance abuse, Working Memory, Reversal Learning

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Abstract

Substance-abusing individuals have been shown to perform poorer on decision-making tasks than non-substance abusing individuals (e.g. Bechara et al., 2001; Grant, Contoreggi, & London, 2000; Sanfey, Loewenstein, McClure, & Cohen, 2006). Research suggests that this difference in performance is likely due to cognitive deficits resulting from impaired functioning of the frontal lobes. Previous research suggests that two important cognitive processes regarding decision making are reversal learning (e.g. Fellows and Farah, 2005) and working memory (e.g. Hinson, Jameson, and Whitney, 2002; Jameson, Hinson, and Whitney, 2004). The purpose of the current research project was to better understand how these processes affect performance on a decision making task and to determine if a previously administered executive stressor can impact current decision making performance. One hundred thirty six individuals categorized as having either high or low working memory functioning were randomly assigned to complete one of three modified Stroop tasks (Stressor, Priming, and Control). Following completion of the modified Stroop task participants completed the Iowa Gambling Task, which is a task requiring appropriate decision making skills to complete successfully.

Statistical analyses examining the quantity and frequency of cards drawn from each deck during the IGT suggested that there was no difference in performance between individuals receiving different modified Stroop tasks or high or low working memory functioning. Analyses examining the monetary outcome of performance on the IGT suggest that there may have been no differential effect between the Stressor and Priming groups, but that these active groups may have performed differently than the Control group. Within the Low working memory block, participants in these active groups may have performed worse than Control group participants, but within the High working memory block participants in these active groups may have performed better than Control group participants. These findings are discussed with regards to previous similar investigations as well as within the broader literature of decision making. Limitations of the current study as well as implications for future investigations are also discussed.

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There is a growing literature showing that substance-abusing individuals perform poorer on decision-making tasks than non-substance abusing individuals (e.g. Bechara et al., 2001; Grant, Contoreggi, & London, 2000; Sanfey, Loewenstein, McClure, & Cohen, 2006). This literature further suggests that this difference in performance is likely due to cognitive deficits resulting from impaired functioning of the frontal lobes, which results in processing information differently. This also results in these individuals responding to information and situations differently. Functional cerebral systems theory of neurological functioning (see Mollet & Harrison, 2006 and Cox & Harrison, 2008 for reviews) can be used to understand how and why these differences occur.

According to Mollet & Harrison (2006) functional cerebral systems theory seeks to understand the functional relationship between brain systems and regions of the brain which interact to produce behavior. For example, throwing and catching a baseball requires using visual systems to track the ball, using motor systems to position arms and limbs, using somatosensory areas to confirm the positioning of the limbs, and pre-motor areas to plan out the movements in advance. While each of these tasks is performed by distinct neural systems in distinct areas of the brain, each of the systems relates to the other through neural connections that run throughout the brain. Mollet & Harrison (2006) explain that this theory views the brain as split into quadrants (left and right frontal as well as left and right posterior), with each quadrant acting in balance with neighboring quadrants such that an increase of activation in one quadrant inhibits activation in neighboring quadrants and vice versa. There is an arousal component to this theory which suggests areas that are aroused will be more likely to respond and respond quicker than other areas, similar to a priming effect. It suggests that optimal functioning under different levels of arousal is reflected by an inverted 'U' such that being under *or* over aroused can result in impaired functioning. Also, functional cerebral systems theory suggests that neurological systems have a limit on the amount of activation that can be sustained before the system ceases to be able to function properly, similar to the limit that humans have on physical exertion. Functional cerebral system theory is an individualized theory which makes predictions based on the functioning within an individual brain, regardless of the level of functioning of that brain.

Decision making

Every aspect of the human experience is impacted by our ability to make advantageous decisions. The ability to make decisions which maximize rewards and benefits while minimizing costs and punishments can be a large factor in achieving goals and reaching objectives. As such, decision making could be considered one of the most important and least understood of all human behaviors. Simply creating an operational definition of decision making can be a complex and difficult task. There are many aspects which could be considered in decision making including long-term outcomes, short-term outcomes, costs, benefits, certainty or uncertainty of an outcome, the discounting of rewards over time, the time frame involved, the level of risk involved, etc. Ernst and Paulus (2005) have offered the following broad definition, "Decision making refers to the process of forming preferences, selecting and executing actions, and evaluating outcomes…we define decision making as encompassing a wide range of behaviors having in common the basic generic structure of input-process-output-feedback." This definition follows the form of Functional Cerebral Systems in suggesting that there are many different behaviors and processes that work together to produce the construct of decision making.

The study of brain-behavior relationships relies in a large part on the study of the effects of damage to specific areas of the brain on specific behaviors. As such, it is only natural that neurological investigations of decision making would examine individuals with damage to specific areas of the brain which impact the ability to make advantageous decisions. Individuals with damage to the ventromedial prefrontal cortex (VMPC) display just such impairments (e.g. Damasio, Tranel, & Damasio, 1991; Damasio, 1996; Bechara, Damasio, & Damasio, 2000; Bechara, 2004).

Individuals with damage to the VMPC display an intriguing mix of deficits related to emotions and decision making, often unable to follow previously observed social conventions or react to changing contingencies when making decisions with important impacts on their lives; however, these individuals retain essentially intact intellect, memory, and attention processes (Bechara, Damasio, & Damasio, 2000; Bechara, 2004; Bechara & Damasio, 2005).

The Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994) was designed to help better understand the effects of risk and uncertainty on decision making, specifically in response to the decision making deficits displayed by individuals with VMPC damage. On this task individuals must draw cards from different decks with each card representing a gain or loss of 'money' with the object of obtaining the largest amount of money possible. Some decks have a higher ratio of losses to gains while others have a higher ratio of gains to losses, resulting in some decks being more advantageous than others. The initial cards drawn from each deck involve gains, and then cards involving loss are introduced. Most individuals begin by drawing more cards from the 'risky' decks because they provide higher levels of gain initially. However, as punishment is encountered, individuals with 'normal' decision making capabilities gravitate toward the ‘safe’ decks with higher gain to loss ratios and away from the ‘risky’ decks.

The IGT has been shown to be sensitive to bilateral lesions of the VMPC (e.g. Bechara et al, 2001, Bechara and Damasio, 2002, Bechara, 2005). Individuals with lesions to the VMPC are impaired in their ability to learn to avoid the ‘risky’ decks on the IGT, consistently drawing from them more often than from the ‘safe’ decks, while normal controls display a learning curve, initially drawing more often from the ‘risky’ decks, but switching to the ‘safe’ decks over time. Individuals with lesions in the VMPC also exhibit deficits on other decision-making tasks such as the Cambridge Gamble Task (e.g. Clark & Manes, 2004; Rogers et al., 1999a).

The impairment of VMPC individuals has been shown to be different than the inability to learn from one’s actions, an impairment that is seen in individuals with bilateral lesions to the amygdala. Bechara, Damasio, Damasio, & Lee (1999) showed that while individuals with lesions to the amygdala do not produce a change in electrodermal activity (galvanic skin response) in response to reward and punishment, individuals with bilateral lesions to the VMPC do, indicating sensitivity to reward and punishment. This study also showed that individuals with lesions to the VMPC differ from normal individuals in that they do not produce anticipatory electrodermal activity when making risky decisions under circumstances of uncertainty (i.e. on the IGT). The lack of anticipatory electrodermal activity is taken as evidence of an inability to utilize past experiences to predict future consequences, resulting in poor performance on the IGT.

Bechara, Tranel, & Damasio (2000) examined the possibility that individuals with lesions to the VMPC are simply hypersensitive to reward and ignore the effects of punishment by altering the magnitude of punishment and reward in the decks of the IGT, but not the overall result of gain or loss. In addition, a variant of the IGT was also developed in which individuals experienced initial losses instead of rewards such that decks initially high in losses resulted in an overall gain in the long run and decks initially low in losses resulted in an overall loss in the long run. They found that individuals with VMPC lesions still preferred decks with high initial gains and higher later losses (bad decks) in the original IGT, but they also preferred the decks with the low initial losses and lower later gains (bad decks) in the variant task. The authors conclude that this supports the 'temporal myopia' hypothesis that individuals with VMPC lesions are focused on immediate gains or losses irrespective of possible future consequences and have trouble altering their response when negative consequences are encountered.

Tranel, Bechara, & Denburg (2002) showed that individuals with right unilateral lesions to the VMPC performed similarly on the IGT to individuals in their previous studies who had bilateral lesions. They also found that these individuals could not maintain employment, had abnormalities related to emotional processing and personality, and met criteria for acquired sociopathy; impairments not found in individuals with unilateral left VMPC lesions. Individuals with left VMPC lesions also performed better than the unilateral right VMPC lesions on the IGT, but not as well as normal controls. One important difference between the right and left VMPC lesion participants was the development of anticipatory electrodermal response. The participants with left VMPC lesions did develop an anticipatory response while the participants with right VMPC lesions did not. This finding indicates that while earlier studies finding impairment involved bilateral lesions, dysfunction in the right hemisphere is necessary *and* sufficient in order for the impairment to manifest while dysfunction in the left hemisphere is neither necessary nor sufficient.

Imaging studies involving tasks such as gambling tasks and two choice guessing tasks have shown that these tasks produce greater activation in the right frontal lobes of individuals. Elliot, Rees, & Dolan (1999) used functional magnetic resonance imaging to show that tasks involving guessing activated the right ventromedial and ventrolateral prefrontal cortex as well as the dorsolateral prefrontal cortex, with increased activity in the ventromedial area in response to increased complexity and uncertainty. Rogers et al. (1999b) showed that gambling tasks increase blood flow to the right inferior and orbitofrontal cortex, which includes the ventromedial and ventrolateral prefrontal cortices. Ernst et al. (2002) examined individuals performing a modified version of the IGT using positron emission tomography during the second block of the administration. This revealed activation primarily in the right prefrontal and parietal areas with the highest correlation between task performance and regional cerebral blood flow to the right ventrolateral prefrontal cortex and anterior insula. Fukui et al. (2005) utilized functional magnetic resonance imaging to examine the time period immediately preceding draws during the IGT. They found that the anticipation of risk activated the medial frontal gyrus and that this activation was correlated with performance on the task.

Taken together, these lesion and imaging studies suggest that the impairment seen on decision making tasks, especially gambling tasks, is related to dysfunction in the right prefrontal cortex, especially the right VMPC. Normal individuals and individuals with lesions in other areas of the brain do not show the same impairments as individuals with lesions to the right VMPC (Bechara, Damasio, Tranel, and Anderson, 1998; Tranel, Bechara, & Denburg, 2002; Clark, Manes, Antoun, Sahakian, & Robbins, 2003). These individuals appear to focus mainly on the rewarding aspects of a choice and ignore the possible negative consequences, similar to the behavior of individuals who do not recognize their substance use is problematic or continue to use in spite of the problems that substance use produces in their lives. Bechara (2005) has suggested that this type of dysfunction underlies addiction and the difficulties that addicted individuals encounter in attempting to alter their use.

Substance users and decision making

Several studies have documented poor performance on the IGT by substance abusing populations such as polysubstance users (Grant, Contoreggi, & London, 2000), heroin users (Petry, Bickel, & Arnett, 1998), cocaine users (Bechara et al., 2001), heavy marijuana users (Whitlow et al., 2004), and alcohol users (Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005; Bechara et al., 2001). It appears that the mechanism that impairs performance on the IGT in substance abusers is not specific to the substance being abused, but generalizes across substances.

The impairment of substance abusers on the IGT is not homogeneous. Bechara et al. (2001) found the performance of substance dependant individuals to fall between the performance of normal controls and individuals with VMPC lesions, with each group being significantly different from each other group. The substance dependent individuals had a particularly wide range of performance on the IGT with some participants from the substance dependent group performing similar to normal controls, while others perform similar to the VMPC lesion group, while still others fell somewhere in between. The authors suggested that substance dependent individuals impaired on the IGT likely have neurological dysfunction that impairs their performance, while other substance dependent individuals do not have this dysfunction. It is also possible that there is a range of dysfunction or impairment due to differences in brain function. It is not clear if this dysfunction precedes or follows the substance abuse.

Cognitive processes in decision making

The VMPC plays a role in decision making and incorporating past experiences into future behavior, but it is not clear how that process is carried out and what rules govern it. Lesion studies as well as neuro-imaging studies have suggested that the VMPC plays a major role in decision making and performance on the IGT in particular. These studies have also suggested the involvement of other areas of the frontal lobes such as the Dorsolateral Prefrontal Cortex (DLPC), an area which is often associated with working memory. Work has been done to better understand the cognitive processes that underlie performance on the IGT in order to better understand the link between brain function and behavior.

Noel et al (2007) attempted to understand how different executive functions might influence performance on the IGT by first administering measures of response inhibition, working memory, and the ability to identify and shift between logical rules. Alcohol dependent individuals were found to perform worse than normal controls on each of these tasks. The alcohol dependent individuals also performed worse than normal controls on the IGT. When the individual measures of executive function were used to predict performance on the IGT in a stepwise regression, only performance on the response inhibition task was retained as a predictor. This task consisted of having individuals complete the final word of a sentence with one that makes sense, and then after a number of trials have the individuals begin to complete the sentence with a completely unrelated word, requiring the inhibition of the initially learned response and the expression of a previously inappropriate response. This task could be considered to be a reversal learning task instead of a response inhibition task.

Reversal learning consists of a task that rewards one behavior and not another. After the individual has learned the contingency for receiving reward, the contingency is reversed and the previously rewarded behavior is now no longer rewarded, and the previously *un*rewarded behavior is now rewarded. The individual must learn that the contingencies have reversed in order to receive any further rewards. Reversal learning has been shown to be impaired in individuals with frontal lobe dysfunction (e.g. Rolls, Hornak, Wade, & McGrath, 1994).

Fellows and Farah (2005a) have suggested that one of the processes (among many possible) underlying performance on the IGT is reversal learning. In this study, individuals with VMPC damage, DLPC damage, and normal controls completed the IGT, a reversal learning task, and an altered IGT. The altered IGT was designed to present cards indicative of the punishment level of each deck initially, instead of the original presentation which places cards indicative of each deck's reward value in the initial draws. They hypothesized that if reversal learning was a key element of performance on the IGT and individuals with VMPC damage are impaired in this ability, then presenting the punishment first should aid the individuals with VMPC damage and improve their score. Individuals with damage to the VMPC and the DLPC were both impaired on the initial presentation of the original IGT, but only the individuals with VMPC damage were impaired on the reversal learning task. The variant of the IGT was administered after a delay of several weeks following the initial testing in most cases. Results of the variant IGT showed that individuals with VMPC damage performed no differently than normal controls, while individuals with DLPC damage were still impaired. The authors concluded that this was evidence of an influence of reversal learning on IGT performance, especially for individuals with VMPC damage. The continued impairment of the individuals with DLPC damage seems to be the result of dysfunction in an area other than reversal learning. These results have not been replicated in a substance abusing population.

The findings of Fellows and Farah (2005a) help clarify the results of the previously mentioned study conducted by Bechara, Tranel, and Damasio (2000) in which variants of the IGT were administered to individuals with VMPC lesions in an attempt to alter their performance and better understand the processes influencing the IGT. An impairment of reversal learning would suggest these individuals preferred the ‘risky’ decks each time because in the original IGT, the ‘risky’ decks have a series of reward cards that are higher in reward than the ‘safe’ decks, setting the contingency that they are more rewarding. When the punishment cards are reached, individuals with reversal learning deficits fail to switch away from the previously reinforced decks to the presently reinforced decks. The same results have been seen when the IGT is altered to present punishment instead of reward initially (Bechara et al., 2000). Individuals still failed to switch to the ‘safe’ decks because that switch required reversal learning.

Noel et al. (2007b) found similar results using a response inhibition go/no go task. The task required participants to respond to alcohol related words and inhibit a response to non-alcohol related words in some blocks of presentation. In other blocks of presentations the participants were required to do the opposite: respond to non-alcohol related words and inhibit a response to alcohol related words. Individuals with a substance disorder committed more errors after shifting from one response set to the other than normal controls.

These findings suggest that the performance on the IGT is contingent on reversal learning. These studies have shown that a pre-existing deficit in reversal learning or a lesion to the VMPC will impair IGT performance. However, an area that has not been explored as well is the production of deficits in non-impaired individuals.

Working memory and stress

Lesions or dysfunction in certain areas of the brain are not the only way to affect frontal functioning, as indicated by functional cerebral systems theory. The frontal cortices are also susceptible to becoming over worked, over utilized, or pushed beyond their capacity, similar to when muscles reach their limit and cease to function optimally. This is why stimuli that activate or utilize a certain area of the brain are often referred to as stressors. ‘Stress’ in this sense is defined as any event or stimulus which causes activation in the neural region of interest. Therefore, different tasks would be considered stressors for different areas of the brain, such as emotional inductions stressing right posterior areas and reading silently stressing left posterior areas. Any ‘executive’ task could be considered a frontal stressor, such as remembering a string of numbers or being exposed to cues that provoke an emotional response. Functional cerebral systems theory also indicates that stressing a certain area of the brain will not only affect that area, but alter functioning in other areas as well, similar to a balance scale (Mollet & Harrson, 2006). Referring to the quadrant model of the brain, stressing the right frontal lobe would result in the activation of the left frontal lobe as well as the right posterior lobe due to resources being pulled away from the inhibitory influence the right frontal lobe exerts on these areas of the brain.

The effect of frontal stressors has been demonstrated through dual concurrent task demands, in which an individual is required to perform two tasks simultaneously that each requires the resources of the frontal lobes. Examples of this would be attempting to remember a string of digits while engaging in a go/no go task or attempting to speak one sentence while writing a different sentence (Pashler, 1994). Each task individually requires frontal lobe involvement, leaving fewer resources to allocate to the other task.

There are many ways in which this dual task demand can be carried out. In a series of experiments conducted using normal college undergraduates, Hinson, Jameson, and Whitney (2002) have shown that performance on a task very similar to the IGT was dependent on working memory load such that higher working memory demands produced poorer performance on the gamble task. This working memory load was also shown to affect anticipatory electrodermal activity (galvanic skin response) during the task, an indication that an individual is not aware they are making a risky choice. Individuals without a working memory load were found to develop electrodermal responses that aided in selecting an advantageous deck, but individuals experiencing a working memory load did not develop advantageous electrodermal responses. The authors conclude that while the VMPC may be important for utilizing information to produce anticipatory electrodermal activity, working memory also plays a role in developing the electrodermal activity. The authors further suggest it is possible that a working memory load prevents encoding of information that is subsequently used to develop anticipatory electrodermal activity.

In a follow up study, Jameson, Hinson, and Whitney (2004) replicated these findings and extended them by showing that working memory specific to attention allocation impairs performance on the IGT, but working memory involving the phonological loop does not. This was shown by having individuals either remember the location of two cards out of a four card array presented before decisions or repeat the word ‘the’ over and over during the task. The effects of these studies were found in the absence of any direct neurological damage, indicating that damage to the prefrontal cortex is not necessary for decision-making deficits to be exhibited.

These findings were extended by Dretsch and Tipples (2008) who showed that the level of impairment on the IGT varied by working memory load. Individuals who experienced a higher working memory load performed poorer than individuals who experienced a lower working memory load.

As demonstrated by Hinson and colleagues, disrupting or otherwise utilizing working memory capacity can produce impairments in IGT performance. Noel and colleagues (2007, 2007b, 2001) have repeatedly shown that substance abusers perform similarly to normal controls when asked to repeat information verbatim, but perform significantly poorer when the information must be rearranged and reported in an order other than what was presented. This provides evidence that working memory, especially working memory related to altering or analyzing information rather than simple storage, may also be impaired in substance abusers and contributes to poor decision making.

The previous studies have provided examples of how ‘stressing’ the frontal lobes can impair performance on executive tasks and decision making tasks in particular. The previous studies also demonstrated that working memory is an important variable in performance on the IGT. It is clear that a stressor experienced during a decision making task can impair the outcome of that task. However, it is also possible that experiencing a stressor can affect future decision making.

Prior stressors and decision making

One way to stress an individual is to induce a certain mood state. Part of the role of the frontal lobes is to regulate emotion and arousal. By inducing an emotional or aroused state, the frontal lobes are forced to exert resources towards regulating that state. According to functional cerebral systems theory, if the posterior regions are activated, this results in a deactivation of the frontal regions due to the inhibitory fibers running between these regions. The frontal regions will then exert resources toward restoring the balance, or regulating the emotion. This activation and inhibition can be considered a stressor, because it uses resources that could otherwise be used to perform the task at hand.

De Vries, Holland, and Wetteman (2008) utilized this method to examine the effect of positive or negative mood on IGT performance. In a series of studies they showed that inducing a positive mood was consistently related to better performance on the IGT than inducing a negative mood. It is possible that this is due to the right frontal lobe's involvement in the regulation of negative moods and emotions while positive moods seem to be regulated to some extent by the left frontal lobe. The most interesting aspect of this finding, however, is that a state induced prior to the administration of the IGT was able to persist and affect individual's performance on the IGT.

Preston, Buchanan, Stansfield, and Bechara (2007) have also shown that inducing an emotional state in an individual can impair future decision making. In this study participants were either told they would be giving a public speech or not told about a public speech prior to completing the IGT. Participants who were anticipating giving a public speech took longer to learn which decks were advantageous and to switch to drawing from them than participants not anticipating giving a speech.

Gray (1999) showed in a series of studies that induced negative mood and self-reported stress levels about upcoming exams in an undergraduate population could adversely affect decision making. The studies did not involve the IGT, but rather a conceptually similar task pitting near term gains against long term losses. Individual's exposed to a series of aversive images displayed poorer performance on the task than individuals exposed to a series of neutral images. They also found that individuals reporting a higher level of stress about upcoming exams preferred the option that offered initial gains and later losses, which is a very similar option that individuals who perform poorly on the IGT make. These results reflect similar findings to De Vries, Holland, and Wetteman (2008), only with a different, but conceptually similar task.

Other studies have shown poor decision making with individuals who go through a stress or anxiety induction, as well as individuals who are currently experiencing a high level of life stress or negative life events (Baradel & Klein, 1993; Cumming & Harris, 2001). However, these studies were with relatively straight forward decision making tasks that did not include a reversal process. It is possible that inducing an emotional or anxious state affects decision making in ways that are not clear due to the general nature of the stressors being used.

Sinha, Lacadie, Skudlarski, and Wexler (2004) have used fMRI to show that emotional states produce activation in the frontal lobes, in addition to the activation that would be expected in limbic areas of the brain. Participants were presented personalized stressful and neutral scripts of life events. Compared to neutral scripts, stressful scripts produced significantly more activation in the right medial prefrontal regions and the ventral anterior cingulate. This has also been shown in individuals attempting to inhibit an emotional response (Beauregard, Levesque, & Bourgouin, 2001). A similar finding has been observed in drug abusers exposed to drug-related stimuli. Higher levels of activation are observed in the prefrontal cortex and anterior cingulate and this activation is highly correlated with self-reported craving (for review see Goldstein & Volkow, 2002). These findings suggest that a strong emotional reaction can stress the frontal lobes, which could in turn affect decision making and reversal learning.

The previous studies have shown that induced emotional states can affect subsequent decision making by ‘stressing’ the frontal lobes, most likely the right medial prefrontal cortex, which is the same area suggested to underlie reversal learning and performance on the IGT.

However, there are no studies that have used a non-emotional stressor focused on the frontal lobes to induce a particular neuropsychological state and then examined the effects of that state on decision making. Functional cerebral systems theory suggests that stressing the frontal lobes will lead to an impairment in future performance on decision making tasks by creating a similar neurological state to that of an emotional stressor.

Current Study

The current study extends the previously reviewed literature by examining the effect of a frontal lobe stressor on subsequent decision making. This study attempted to further understand the role of cognitive processes such as reversal learning and working memory on decision making. This was examined by applying a reversal learning stressor prior to the completion of a decision making task. Also, this study examined the effect of current working memory capacity on decision making by examining the performance of individuals with high and low working memory functioning as measured by a working memory task.

By utilizing functional cerebral systems theory two hypotheses were proposed concerning the effect of administering a reversal learning stressor on future decision making. A high enough dose of the stressor was expected to produce arousal which is dysfunctional according to the inverted ‘U’ relationship between arousal and performance. The production of these high levels of activation should also impair future activation and create a state of ‘fatigue’ due to depletion of resources. Alternately, a lower dose of the stressor was expected to provide beneficial effects by producing arousal which falls in the middle of the inverted ‘U’ and not depleting resources to levels that impair activation. This effect is conceptually similar to priming reversal learning, making it more likely that this area of the brain will be utilized for future tasks.

Priming occurs when a stimulus increases the likelihood of a certain behavior being exhibited in response to a later stimulus, or increases the speed that a response is made. Priming effects have been shown in many situations, but are perhaps most striking in the substance use literature (for reviews see: Shalev, Grimm, & Shaham, 2002; de Wit, 1996). Studies have shown that after training laboratory animals to respond for a dose of a substance and then subsequently extinguishing the effect, a single dose of the substance can reinstate responding for the drug at pre-extinction levels (eg. Stretch & Gerber, 1973). Priming effects have also been reported in humans, as shown by reported increases in craving by abstinent substance abusing humans after a small dose of the substance (eg. Ludwig & Wikler, 1974). Priming semantic or affective responses has also shown strong and consistent results (for review see Storbeck & Clore, 2008). In these studies response times for categorizing a word are faster if that word is preceded by a word in the same category (e.g. categorizing 'Doctor' as a word quicker if it is preceded by the word 'nurse' rather than the word 'flower').

Many theories have been proposed to explain priming effects. In substance use literature these theories are often related to operant or classical conditioning, or address motivational states (de Wit, 1996). Cognitive explanations for priming effects generally involve spreading activation within a cognitive network of related ideas (Storbeck & Clore, 2008). Functional cerebral systems theory suggests that the particular area of the brain that had been previously utilized is subsequently aroused and more likely to respond to stimuli in the immediate future. This would also result in neighboring areas being inhibited to a degree, making them less likely to respond.

The final aim of this study was to explore the predictions made using functional cerebral systems theory by administering two doses of a reversal stressor to individuals. The high level dose was designed to deplete an individual's resources and increase arousal to dysfunctional levels in order to disrupt subsequent performance on the IGT. The low level dose was designed to prime an individual to be more likely to utilize those same resources in the immediate future on the IGT.

Study Hypotheses

Hypothesis One: Individuals who experience a reversal learning stressor will perform poorer on the decision making task than individuals who do not experience a stressor. Individuals who experience a reversal learning primer will display better performance on the decision making task than individuals who do not receive a reversal learning primer.

Hypothesis Two: Individuals with poorer working memory functioning will perform poorer on the decision making task than individuals with higher working memory functioning.

Hypothesis Three: An interaction is expected between working memory functioning and experimental condition such that for individuals with low working memory functioning the effect of the reversal learning stressor will be amplified while the effect of the reversal learning primer will be attenuated, and for individuals with high working memory functioning the opposite was expected with the effect of the reversal learning primer amplified and the effect of the reversal learning stressor attenuated.

Methods

Participants

One hundred thirty six participants (79 males, 57 females) were recruited for the current study from the student body at Virginia Tech through the SONA computer network. Participants who reported a history of brain damage, concussion, unconsciousness, or any type of head trauma were deemed ineligible to participate in the laboratory portion of the study. Participants were separated into two blocks based on working memory functioning as determined by their performance on the Spatial Span subtest from the Wechsler Memory Scale – III (WMS-III). Initial eligibility criteria were set so that participants receiving a scaled score of 8 or less or 12 or more on the Spatial Span subtest were classified as Low or High on working memory, respectively. These cutoff scores represent the upper and lower 25% of the population according to the WMS-III normative data. Due to difficulty in recruitment and incongruence between the Wechsler normative sample and undergraduate populations, eligibility criteria were altered such that participants receiving a raw score of 16 or less would be classified as Low Working Memory and participants receiving a raw score of 20 or more would be classified as High Working Memory. These cut off scores were determined based on data previously gathered from undergraduate samples and more accurately reflect the upper and lower 25% of undergraduate populations (Mertens et al., 2006; Shelton et al., 2009). Participants received research credit for their participation, and were also eligible to receive one of three $20 Amazon gift cards based on their performance on the experimental tasks.

Design Overview

The design is a 2 x 3 between-subjects factorial with one blocking factor (Working Memory) and a manipulated independent variable (Group). Participants were separated into one of two blocks based on working memory function. One block consisted of individuals classified as high on working memory function (n=85) and the other block consisted of individuals classified as low on working memory function (n=51). Within the respective blocks participants were randomized to one of three conditions: A reversal learning stressor condition (Stressor, n=48), a reversal learning priming condition (Priming, n=41), and a control condition that did not experience a stressor or primer (Control, n=47). After completing the appropriate task for their condition all participants completed the Iowa Gambling Task, which was the primary dependent variable. Participants also completed a series of questionnaires assessing characteristics such as personality, hostility, and affect.

Procedure

Screening. Participants first attended a screening session in which they completed questionnaires online using the 'survey.vt.edu' system in order to determine their eligibility to participate in the laboratory portion of the study. Questions were included to ensure that participants were paying attention while filling out questionnaires online. During this session participants completed measures related to sensitivity to punishment, sensitivity to reward, and hostility. During the screening session participants were also administered the Spatial Span and Letter Number Sequencing subtests from the WMS – III.

Following the completion of the Working Memory assessments and a review of the Medical History form, the eligibility of participants was determined. Eligible participants were invited to participate in the laboratory session. Participants who accepted the invitation were given a copy of the informed consent form for the laboratory session and scheduled for an appointment. Ineligible participants were informed of their ineligibility and thanked for their participation.

Laboratory session. Individuals who met eligibility requirements were randomized to one of three conditions (Stressor, Priming, or Control) within their respective Working Memory

(WM) block. This study utilized three modified versions of the Stroop task (Stroop, 1935) to manipulate the independent variable of Reversal Learning. In all three conditions participants were seated at a desk in front of a desktop computer. Participants were presented with the informed consent form and given a chance to review it, were verbally presented an overview of the study and offered a chance to address questions or concerns regarding participation in the study, and then asked for their consent to participate in the study. Once participants consented to participate the experiment was begun. The laboratory session consisted of completing the PANAS questionnaire, then the modified Stroop task, followed by the IGT, and finally the PANAS questionnaire again.

Each version of the Stroop task was administered on a PC computer using the software program Psychology Experiment Building Language (PEBL; Mueller, S. T., 2009). Each stimulus word was displayed in the center of the screen with the three response options (Red, Blue, or Green) displayed below the word. The stimulus words were presented in 30 point font. The participant was required to press the key on the keyboard (the number 1, 2, or 3) corresponding to the correct response. Participants were allowed to use their hand of preference to make responses. The stimulus word was displayed on the screen until a correct response was made by the participant. Feedback about each response was presented above the stimulus word as “Correct” or “Incorrect”. Following a correct response the next stimulus word was presented. If the participant made an incorrect response, the original stimulus word remained on the screen until a correct response was provided. Response latencies were measured in milliseconds beginning with the presentation of the stimulus word. Each version of the Stroop task was presented in four blocks of 25 words with instructions read to the participants between each block of word presentations.

In the Stroop task presented to the Stressor condition (Stressor Stroop), color words were presented in non-corresponding color ink. Half of the words in the Stressor Stroop were underlined. Participants were asked to press a button that either corresponded to what the word said, or the color of the ink, depending on if the word was underlined or not.

To begin the experiment an introductory script was presented. Participants in the Stressor condition were read the following script: "In this task you will see a series of words presented on the computer screen. The words will be presented in different colors. There will be two aspects to your task for this test. When words are presented and are not underlined, you will need to press the button that correctly corresponds to the color in which the word is presented. When the presented word *is* underlined your task will be to press the button that correctly corresponds to what the word says, regardless of the color in which it is presented. Do you have any questions?" At this point a page with four example word presentations was shown to the participant, two underlined and two not underlined. The participant was asked to respond verbally to each word according to the instructions just presented to them. If any errors were made the participant was corrected and asked to repeat the practice presentations. Once the participant successfully completed the practice administrations he or she was administered the first block of the computerized modified Stroop task.

After completing the first block of word presentations participants in the Stressor condition were read the following instructions: "For this next block of word presentations you will need to respond in the opposite manner to the previous block of word presentations. When words are presented and are not underlined, you will need to press the button that correctly corresponds to what the word says, regardless of the color in which it is presented. When the presented word *is* underlined your task will be to press the button that correctly corresponds to the color in which the word is presented. Do you have any questions?" Any questions were answered and the four example words were presented again. Participants were asked to respond according to the rules just presented to them. Upon successful completion of the practice administration the second block of word presentations was administered. After the second block was completed, the same instructions that were presented before the first block were presented before the third block and an additional practice administration was completed. Once the third block was completed, the same instructions which were read before the administration of the second block were read before the administration of the fourth block of word presentations followed by another practice administration. This resulted in the response contingencies reversing between each block of the Stroop administration.

Next, participants were administered the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994). The IGT was administered on the same computer as the Stroop task using the computer program PEBL. The IGT was designed to evaluate an individual's decision making ability, especially under situations of uncertainty and risk. Participants began the task with $2000.00 and were required to draw cards from one of four decks. Each time a card was drawn the resulting transaction on the card occurred. Each card drawn added a certain amount of money to the participant's total, but some cards also subtracted a certain amount. Each deck consisted of a different proportion of gain and loss, with two decks (A & B) resulting in an initially larger gain, but eventually resulting in an overall loss per ten cards. The other two decks (C & D) provide smaller initial gains, but result in an overall gain per ten cards.

Participants were read the following instructions before the administration of the IGT: "I cannot tell you much about this next task; however, your goal for this task is to end with the most money possible. You will begin this task with $2000.00 and will gain or lose money based on the cards you will draw from these four decks. This task will consist of 100 rounds. Each round will consist of drawing a card and adding to or subtracting from your total the amount of money indicated by the card. There is nothing about the appearance of the cards or the position of the decks that will indicate whether one deck is better than another, or anything about the content of the next card in a deck. You will simply need to determine a strategy from your experiences drawing cards from each deck. Do you have any questions about this task?" Any questions about the task were answered and participants were told about the incentive for performing the task using the following script, "I would like to encourage you to do the best you can on this task, one reason is that individuals who end up with the most money on this task will receive a $20 Amazon gift certificate." Participants then completed the IGT.

After completing the IGT participants were asked to complete the PANAS. Participants were then debriefed about their participation in the study, thanked, and escorted out of the lab.

Participants in the Priming condition followed very similar procedures to those in the Stressor condition. The instructions and scripts read to participants in the Priming condition, as well as the procedures followed, were identical to those in the Stressor condition. The only difference between the two conditions was the Stroop task that was administered. Instead of half of the words being underlined as in the Stressor Stroop, the Stroop task presented to participants in the Priming condition (Priming Stroop) had only 10% of the words underlined. The task was still the same, only the intensity was lower in the Priming condition.

Control group participants also had a very similar experience to the Stressor group participants, only they completed the Control Stroop rather than the Stressor or Priming Stroop. The Control Stroop task presented color words in their corresponding color of ink and participants were asked to respond by pressing a button that corresponded to what each word said.

After completing the initial administration of the PANAS, participants in the Control condition were read the following script: “In this task you will see a series of words presented on the computer screen. The words will be presented in colored ink. Your task is to read each word and press the key which corresponds to the color indicated by what the word says, any questions?” At this point a page with four example word presentations was shown to the participant and the participant was asked to respond to each word according to the instructions just presented to them. Participants in the Control condition were then administered four blocks of the Control Stroop task. Each block consisted of the instructions read to the participant followed by a practice administration, then 25 word presentations. After completing the final block of the Control Stroop, participants in the Control condition followed the same procedures as the Stressor and Priming conditions.

Measures

The Behavioral Activation/Behavioral Inhibition Scales (BIS/BAS; Carver & White, 1994). The BIS/BAS scales consist of twenty-four statements to which an individual indicates his/her agreement on a 4-point Likert scale (1 = very true for me to 4 = very false for me). An example of a BIS item would be: “I worry about making mistakes” whereas an example of a BAS item is: “It would excite me to win a contest.” Scoring followed the procedure suggested by Carver and White (1994) to create three BAS subscales (Drive, Fun, Reward) on one BIS subscale. Higher scores on the BAS subscales indicate that behavior is guided by a tendency to approach positive outcomes in the respective category. Higher scores on the BIS subscale indicate that behavior is guided by a tendency to avoid negative outcomes. The internal consistency of the BIS/BAS scales has been shown to range from .66 to .76 (Carver & White, 1994). In the current study the internal consistency for each scale was adequate except for the BIS (Drive=.73, Fun=.75, Reward=.67, BIS=.32). The BIS/BAS questionnaire was administered in order to understand the impact of approach and avoidance behaviors on decision making performance.

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS was used to assess participants' emotional state immediately prior to beginning the modified Stroop task and upon completion of the IGT. The PANAS is a 20-item questionnaire that measures the mood of an individual. Two subscales were derived (positive and negative) based on the procedures described by Watson, Clark, and Tellegen (1988). Higher scores on the positive subscale indicated increased positive affective states and higher scores on the negative subscale indicate increased negative affective states. It has been shown to have good internal reliability as well as convergent and discriminate validity (Watson, Clark, & Tellegen, 1988). In the current study each subscale of the PANAS demonstrated adequate internal consistency (Positive=.87, Negative=.77).

Sensitivity to Punishment and Sensitivity to Reward questionnaire (SPSRQ; Torrubia et al., 2001). This is an alternate scale to the BIS/BAS scales that offer an understanding of how an individual responds to reward and punishment. Two subscales can be derived from this questionnaire (Sensitivity to Punishment / Sensitivity to Reward) based on the procedures suggested by Torrubi et al. (2001). Similar to the BIS/BAS scales, higher scores on the Sensitivity to Reward subscale suggests that behavior is guided by a tendency to approach positive outcomes and higher scores on the Sensitivity to Punishment subscale suggests that behavior is guided by a tendency to avoid negative outcomes. These subscales have been shown to have good reliability and validity (O'Connor, Colder, & Hawk, 2004; Torruba et al., 2001) and have also been used in substance use research to better understand the effect of previous substance use history on current substance use behavior (Simons, Dvorak, & Batien, 2008; Simons & Arens, 2007). In the current study the scales demonstrated adequate internal consistency (Reward=.70, Punishment=.74). This questionnaire was administered in order to understand how sensitivity to reward and punishment may affect decision making performance.

Cook Medley Hostility Scale. Hostility has been shown to be related to dysfunction in the right frontal lobe, especially the orbitofrontal cortex (eg. Cox & Harrison, 2008; Williamson & Harrison, 2003). The Cook Medley has been used to differentiate hostile from non-hostile individuals and has been shown to be a valid measure of hostility (e.g. Williamson & Harrison, 2003; Demaree & Harrison, 1997; Contrada & Jussim, 1992). A single hostility factor is computed by summing responses in the hostile direction with higher scores indicating more hostility. The internal consistency for the CMHS in the current study was .79. This scale was administered in order to explore the relationship between hostility and decision making.

Letter-Number Sequencing. The Letter-Number Sequencing subtest from the Wechsler Memory Scale-III is suggested to be a test of auditory/verbal working memory. Individuals are read increasingly long strings of letters and numbers in a non-sequential order and are asked to report the numbers first, from lowest to highest, followed by the letters, in alphabetical order. Participants' total score is a sum of the number of correct trials, with higher scores indicating an increase in working memory capacity. This test has been shown to have internal validity and test-retest reliability coefficients between .80 and .89 (Strauss, Sherman, & Spreen, 2006).

Spatial Span. The Spatial Span subtest of the Wechsler Memory Scale-III was developed as a visual-spatial analog to the Digit Span subtest. A board with an array of blocks attached to it is presented and the blocks are touched in a certain order which individuals are asked to replicate, first identically, then in the opposite order of the presentation sequence. Total scores are computed by summing the number of correct responses in both the forward and backward conditions with higher scores indicating an increase in working memory capacity. This test has been shown to have adequate validity and test-retest reliability with coefficients falling between .70 and .79 across a range of investigations (Strauss, Sherman, & Spreen, 2006).

Participants also completed a brief demographic and medical history questionnaire.

Results

Statistical analyses were conducted using the SPSS 17.0 statistical package. For all analyses the α-level was set at 0.05. Post-hoc comparisons were conducted using Fisher's Least Significant Difference (LSD) multiple comparison procedure. This was selected because it controls the family-wise error rate at $\alpha = 0.05$ when there are no more than three treatment levels. When interpreting results p values less than 0.05 were considered significant. Questionnaire data were lost for two participants due to computer malfunctions and this is noted where relevant.

Demographics and Self Report Questionnaires.

Descriptive statistics for demographic and self-report data for each WM block can be seen in Table 1. The same data can be seen for each group in Table 2. The average age of participants was 19.67 years. Seventy-four percent of participants were Caucasian, eleven percent were Asian-American, and seven percent were African-American. Fifty-eight percent of the sample was male. In order to examine differences between the Reversal Learning Groups (RLG) on demographic, self-report, and WM variables, oneway ANOVA were performed for continuous variables and Chi-Square analyses were performed for categorical variables. To examine differences among the WM blocks, 2-tailed *t*-tests were performed for continuous variables and Chi-Square analyses were performed for categorical variables.

Randomization Check.

In order to detect any failures in the randomization process, the RLGs were compared on all demographic and self-report variables (see Table 2). There was a significant difference between RLGs on the Drive subscale of the BIS/BAS questionnaire [$F(2, 131) = 6.50$, $p=.002$]. Post-hoc comparisons indicated that participants in the Stressor group scored significantly lower than participants in either the Priming group [Mean Difference = 0.967, $p=.029$] or the Control group [Mean Difference = -1.52, $p=.001$]. The difference between RLGs on the Letter-Number Sequencing task trended towards significance [$F(2, 133) = 3.00$, $p=.053$]. Post-hoc comparisons indicated that participants in the Priming group scored significantly higher than participants in the Stressor group [Mean Difference = 1.08, $p=.023$] while the difference between the Priming and Control group trended toward significance [Mean Difference = 0.93, $p=.052$]. There was no significant difference between participants in the Stressor and Control groups [Mean Difference = -0.15, $p=.737$]. There were no other significant differences between the RLGs on other demographic or self report variables. Overall these findings indicate that randomization was successful in creating similar groups of participants, with the few exceptions noted above. The most notable exception was the significantly higher scores on Letter-Number Sequencing in the Priming group. Analyses were utilized to examine these variables as covariates. Models in which these variables were significant covariates will be noted, otherwise the model without covariates will be reported.

Analysis of WM Block assignment.

In order to identify differences in those categorized in the High and Low WM blocks, analyses were run to compare these blocks on the measured Working Memory variables. As expected, on the Spatial Span task there was a significant difference between WM blocks [$t(134) = -24.30$, $p=.0001$] which indicated that participants in the High WM block scored higher than participants in the Low WM block (see Table 1). There were also significant differences in performance on the Letter Number Sequencing task, which also taps working memory [$t(134) = -4.74$, $p=.0001$]. Participants in the High WM block scored higher than participants in the Low WM block. Further analyses were run in order to examining any differences between the WM blocks on self-report and demographic variables. There were significantly fewer females in the Low WM block ($X^2_1 = 5.24$, $p=.031$) and participants in the High WM block scored higher on the CMHS [$t(132) = -2.16$, $p=.032$]. The differences in gender and CMHS scores between the WM blocks were unexpected; however, participants were not randomized to WM block which increased the likelihood of between WM block differences. These differences will be addressed using covariate analyses where appropriate.

Manipulation Check.

In order to examine the effectiveness of the modified Stroop Tasks in creating three seperate conditions, 3 (RLG) x 4 (Time) Mixed Design ANOVA were run. RLG (Stressor, Priming, or Control) was a between subjects variables and Time (Administration 1, 2, 3, or 4) was a within subjects variable. Response time and errors committed during each administration assessed the difficulty of the task and were expected to increase systematically across the Control, Priming, and Stressor groups, respectively.

Response Time. Figure 1 shows response times during each block of the modified Stroop task for each RLG. For this analysis there was a significant main effect of Time [F(3, 131) = 44.49, *p*=.0001] indicating that response times changed significantly as a function of Block. A main effect of RLG was also observed [F(2, 133) = 110.35, *p*=.0001]. Post-hoc comparisons indicated that the Stressor group (*M*=2026.20, *SD*=606.88) displayed significantly slower response times than the Priming group (*M*=1449.15, *SD*=337.46) [Mean Difference = 577.04, *p*=.0001], which displayed significantly slower response times than the Control group (*M*=747.22, *SD*=186.40) [Mean Difference = 701.94, *p*=.0001]. There was also a significant interaction between Time and RLG [F(6, 264) = 5.99, *p*=.0001]. As Figure 1 demonstrates, response times in the Control group decreased from the first administration to the second administration, and then remained relatively constant. This is contrasted with response times in the Stressor and Priming groups which decreased from the first to the second administration as well as from the second to the third administration before remaining relatively constant from the third to the fourth administration.

Errors. Figure 2 displays the number of errors committed by participants during each administration of the Stroop task. For this analysis there was a significant main effect of Time [F(3, 131) = 6.45, *p*=.0001] indicating that the number of errors committed changed significantly as the administration progressed. A main effect of RLG was also observed [F(2, 133) = 42.33, *p*=.0001]. Post-hoc comparisons indicated that the Stressor group (*M*=3.46, *SD*=2.34) displayed significantly more errors than the Priming group (*M*=1.90, *SD*=1.22) [Mean Difference=1.56, *p*=.0001], which displayed significantly more errors than the Control group (*M*=0.21, *SD*=0.36) [Mean Difference = 1.68, *p*=.0001]. There was a significant interaction between Time and RLG [F(6, 264) = 2.39, *p*=.029], which Figure 2 suggests is likely due to the contrast between the performance of the Control group, which was relatively constant over time and the performance of the Stressor and Priming groups in which the number of errors increased from the first to the second administration, decreased from the second to third administration, and then increased again from the third to fourth administration.

Taken together, the response time and error analyses support the conclusion that the experimental manipulation was effective in providing two different levels of a reversal learning stressor and a non-stressful attentional control task. Participants in the Stressor group had the longest reaction times and committed the most errors; participants in the Priming group had shorter reaction times and committed fewer errors than the Stressor group; and participants in the Control group had the shortest reaction times and committed the fewest errors overall. The increase in the number of errors committed by the Stressor and Priming groups during the reversal blocks provides additional support for the reversal learning aspect of the task. This pattern of responding suggests that the reversal component of the task added an element of difficulty above that of the Stroop task itself and likely provided the reversal learning stressor that was intended. These results suggest that the experimental manipulation was successful in subjecting the participants to a strenuous reversal learning stressor; a less strenuous reversal learning task intended to serve as a primer; and an even less strenuous control task.

IGT Analyses.

Performance on the IGT was examined using 3 (RLG) x 2 (WM) x 4 (Block) Mixed Design ANOVA in which RLG (Stressor, Priming, or Control) and WM (Low or High) were between subjects variables and Block (1, 2, 3, or 4) was a within subjects variable. The IGT is typically examined in four blocks of 25 cards, corresponding to the chronological order in which the cards were drawn. Thus, the first 25 cards drawn are considered Block 1, the second 25 are considered Block 2, etc. Within each block the sum of cards drawn from the 'bad' decks (A & B) is subtracted from the sum of the cards drawn from the 'good' decks (C & D) to produce a performance score ((C+D) – (A+B)), which is referred to as the "Algorithm" score. If this score is negative, it reflects that the participant drew more cards from the 'bad' decks during that block. If this score is positive then the participant drew more cards from the 'good' decks during that block. The magnitude of the number indicates the level of preference for 'good' or 'bad' decks.

Other ways to examine performance on the IGT include examining the amount of gains during each block, the amount of loss during each block, the total result of gains minus loss during each block, the total amount of money at the end of each block, and the number of cards drawn from individual decks during each block.

In general, the same pattern of findings was expected, regardless of the outcome variable examined. According to hypothesis one, a main effect of RLG was expected demonstrating that the Priming group performed the best overall, followed by the Control group, and finally the Stressor group. According to hypothesis two, a main effect of WM was expected demonstrating that participants in the High WM block performed better than participants in the Low WM block. And finally, according to hypothesis three, an interaction was expected between WM and RLG such that within the Low WM block the effect of the Stressor Stroop was accentuated while the effect of the Priming group was attenuated, and in the High WM block the opposite was expected with the effect of the Priming group accentuated and the effect of the Stressor group attenuated.

Algorithm. A 3 (RLG) x 2 (WM) x 4 (Block) Mixed Design ANOVA was run using the Algorithm score at the end of each 25 card block as the dependent variable. Figure 3 displays the Algorithm score during each block by RLG and WM. There was a significant main effect of Block [F(3, 128) = 16.27, *p*=.0001], no significant main effect of RLG [F(2, 130) = 0.29, *p*=.752], and no significant main effect of WM [F(1, 130) = 0.26, *p*=.610]. There was no significant interaction between Block, RLG, and WM [F(6, 258) = 0.67, *p*=.672], Block and WM [F(3, 128) = 0.22, *p*=.880], Block and RLG [F(6, 258) = 1.42, *p*=.206], or WM and RLG [F(2, 130) = 1.55, *p*=.217]. Repeated Measures ANOVA were run in order to examine the main effect of Block. These analyses revealed that the Algorithm score increased significantly from Block 1 (*M*=-2.60, *SD*=7.56) to Block 2 (*M*=2.21, *SD*=8.04) [F(1, 135) = 28.54, *p*=.0001], but did not change significantly from Block 2 to Block 3 (*M*=3.54, *SD*=8.85) [F(1, 135) = 2.68, *p*=.104], or from Block 3 to Block 4 (*M*=2.68, *SD*=9.92) [F(1, 135) = 1.35, *p*=.247]. This analysis suggested that while participants' Algorithm score improved over time, there was no significant impact of WM or RLG assignment on that improvement.

Total Money. An alternative way to examine outcomes of the IGT is by using the total amount of money a participant has at the end of each block of 25 cards. This was done using a 3 (RLG) x 2 (WM) x 4 (Block) Mixed Design ANOVA using the Total Money at the end of each 25 card block as the dependent variable. A graph of these data can be seen in Figure 4.

This analysis revealed a significant main effect of Block [(3, 128) = 44.26, *p*=.0001], but no main effect of WM [F(1, 130) = 0.31, *p*=.580] or RLG [F(2, 130) = 0.57, *p*=.569]. There was also no significant interaction between Block, RLG, and WM [(6, 258) = 0.70, *p*=.654], Block and RLG [F(6, 258) = 1.46, *p*=.194], or Block and WM [F(3, 128) = 2.02, *p*=.115]. The interaction between WM and RLG [F(2, 130) = 3.02, *p*=.052] trended towards significance.

Repeated Measures ANOVA were run in order to examine the main effect of Block. These analyses suggested that participants' total amount of money significantly decreased from Block 1(*M*=2607.17, *SD*=659.23) to Block 2 (*M*=1910.48, *SD*=632.27) [F(1, 135) = 116.20, *p*=.0001] and from Block 2 to Block 3 (*M*=1720.22, *SD*=664.97) [F(1, 135) = 12.25, *p*=.001], and then significantly increased from Block 3 to Block 4 (*M*=1840.63, *SD*=726.73) [F(1, 135) = 4.58, *p*=.034].

A graphical depiction of the WM by RLG interaction can be seen in Figure 5. An examination of the average Total Money collapsed across Blocks suggested that within the Low WM block participants in the Priming group performed the worst (*M*=1810.29, *SD*=376.07), while participants in the Control group performed the best (*M*=2148.05, *SD*=499.26). The means also suggested that the opposite was true in the High WM block; participants in the Priming group performed the best (*M*=2101.30, *SD*=477.57) while participants in the Control group performed the worst (*M*=1933.06, *SD*=442.91). Participants in the Stressor group fell between the other two groups in each block. Oneway ANOVA suggested that within each WM block the between RLG differences were not statistically significant [Low, F(2, 48) = 1.94, *p*=.155; High, F(2, 82) = 1.29, *p*=.280]; however, *t*-tests run between the Priming and Control group data suggested that these two groups were significantly different from each other in the Low WM block [Low, *t*(31) = -2.20, *p*=.035; High, *t*(53) = 1.35, *p*=.183]. *T*-tests run within each RLG suggested that performance between WM blocks was only significantly different in the Priming group, which performed better in the High WM block [Stressor, *t*(46) = -0.42, *p*=.675; Priming, *t*(39) = -2.09, *p*=.043; Control, *t*(45) = 1.51, *p*=.138].

Other IGT Analyses. Analyses were run to examine other outcome variables of IGT performance such as Gains, Losses, Results, and number of draws from the different decks in an identical manner to the analyses run for the IGT Algorithm and Total Money variables. Analyses related to the number of cards drawn from different decks were essentially identical to the previous analysis run for the IGT Algorithm with a significant main effect of Block but no other significant main effects or interactions. Analyses related to monetary outcomes were similar to the analysis run for Total Money; however, none of the WM by RLG interactions reached significance [Gains, $F(2, 130) = 1.55$, $p<.217$; Loss, $F(2, 130) = 1.89$, $p<.156$; Result, $F(2, 130) = 1.80$, $p<.170$]. The results of these additional analyses will not be formally presented here due to their similarity to the previously presented analyses.

Personality.

Correlation and regression analyses were run in order to examine how performance on the IGT is related to personality variables of approach, avoidance, and hostility. It was expected that individuals scoring high on approach related personality variables would be influenced to a greater degree by the rewarding aspects of the IGT task. Similarly, individuals scoring higher on avoidance related personality variables were expected to be influenced to a greater degree by the punishing aspects of the IGT. Individuals scoring higher on hostility related personality variables were expected to be influenced more by the short term aspects of the IGT task. Thus, approach and hostility variables were expected to be negatively correlated with overall IGT performance and avoidance variables were expected to be positively correlated with overall IGT performance.

Correlations. In order to understand how personality variables influenced performance on the IGT, bivariate correlations were examined between the subscales of the BIS/BAS, the SPSQR, and the CMHS, with the IGT Algorithm and Total Money outcome variables. The results of these correlations presented for each block of the IGT administration for the Algorithm score can be seen in Table 4 and Total Money can be seen in Table 5. These results indicate that the only significant correlation between personality variables and performance on the IGT occurred between the Fun subscale of the BIS/BAS and the IGT Algorithm during the fourth block. Given that this relationship is not supported at other time points or with similar variables it is likely spurious.

Regressions. Regression models were created in order to further investigate the role of Personality variables on IGT performance. In order to examine the effect of personality beyond the experimental manipulation, dummy variables were created for membership in each RLG and included in Step One along with participant's raw scores on the WM tasks. Step Two included scores on the BIS/BAS subscales, the SPSRQ subscales, and the CMHS. IGT outcome variables chosen as dependent variables for this analysis were the Algorithm score during each block and Total Money at the end of each block. The results of these regression analyses are presented in Table 6. The model was not able to significantly predict performance on the IGT at any time point. The results of these analyses do not offer support for the hypothesis of a relationship between the BIS/BAS constructs and performance on the IGT.

Discussion

The current study sought to better understand the processes involved in decision making by investigating if those processes could be influenced through the effects of a frontal lobe executive functioning stressor. Previous research has suggested that the frontal lobes, and the ventromedial prefrontal cortex in particular, play an important role in the processes of decision making and that altering their functioning should affect decision making in predictable ways.

The current study sought to use two reversal learning executive functioning tasks to alter subsequent decision making. A stressor task was utilized in order to ‘fatigue’ the resources of the frontal lobes and disrupt the ability of participants to utilize these resources in a subsequent decision making task, thereby impairing decision making. A priming task was utilized in order to prepare the resources of the frontal lobes for future use, and thereby improve subsequent decision making. These tasks were examined under conditions of low and high working memory capacity with the expectation that working memory capacity would moderate the effect of the task on subsequent decision making. The effect of several personality characteristics on decision making was also examined. Results did not support the hypotheses in expected ways. There was no clear effect of the reversal learning executive functioning task on decision making performance, and there was no difference in decision making performance between low and high working memory capacity conditions. Also, personality characteristics typically associated with impulsivity or a focus on short term outcomes were not correlated with decision making performance.

When examining the Algorithm score, which is the conventional outcome variable of IGT performance, there was no significant effect of the RLG manipulation or WM block on IGT performance. The same was true for any analysis of outcome variables associated with deck preference. However; examining the total amount of money a participant has accrued throughout the IGT administration suggested that RLG performance may have been moderated by WM block such that the performance of participants in the Low WM block who received a reversal learning Stressor or Primer may have been adversely impacted compared to those who did not. In the High WM block, the performance of participants who received a reversal learning Stressor or Primer did not appear to have been adversely impacted and instead may have benefitted compared to those who did not. This interaction was not replicated in other analyses involving monetary gain or loss.

The different results for each outcome variable were unexpected. However, the interaction between WM and RLG in the Total Money analysis, as well as the graphical depictions of IGT Algorithm performance in Figures 3, 6, and7, prompted a possible alternate interpretation of the reversal learning Stressor and Priming tasks. Initially it was expected that the performance of these groups would fall on either end of a spectrum, with the Control group in the middle. The initial analyses suggested the exact opposite; the performance of these two groups was similar and differed from the performance of the Control group. It appears that the interaction between WM block and RLG was not statistically significant in the Algorithm analysis in part due to the large variability in performance between participants in the same RLG and WM block, which is demonstrated by the large Standard Deviations of the Algorithm variables seen in Tables 1 and 2. Standard Deviations were not as pronounced for the Total Money variable, which likely resulted in the discrepancy between analyses with one interaction appearing significant and the other not. Analyses utilizing possible covariates from the various self-report measures failed to reduce the variability in the Algorithm scores. This suggests that there may be an important variable which was not measured that accounted for much of the variability in IGT deck preference in the current study.

Another possible explanation is that participants were aware of their total amount of money at all times during the IGT task and told that maximizing this number was the objective of the task, when the actual objective of the task was to choose cards from decks with the most rewarding cost/benefit ratio. These goals are assumed to be one and the same, and mathematically this is true. However, a study conducted by Lin et al. (2007) suggests that the nature of the cost/benefit ratios of certain decks may result in decision making which does not reflect the anticipated pattern, but rather produces a preference for Deck B, referred to as the "prominent Deck B" phenomenon. The authors suggest this may be due to the infrequency of punishment in this deck relative to the frequency and quantity of reward.

The preference for powerful immediate rewards in the face of severe negative consequences in the long term is not a phenomenon unique to the IGT, but rather a common occurrence across many types of decisions. (e.g. substance abuse, gambling, diet, financial decisions, etc.). The current study sought to offer some insight into this phenomenon by examining the relationship of personality variables on IGT performance. Unexpectedly, there were no meaningful correlations between measures of IGT performance and measures of approach, avoidance, or hostility personality variables and regression analyses failed to provide support for the relationship as well.

The results of the current study did not support the hypotheses which suggested that the Priming group would outperform the Control group, which would outperform the Stressor group, that the High WM block would outperform the Low WM block, and that the effect of the Stressor group would be amplified in the Low WM block and attenuated in the High WM block while the effect of the Priming group would be amplified in the High WM block and attenuated in the Low WM block. The relationship between personality variables and IGT performance was also not supported.

Limitations

The lack of support for the hypotheses in the current study could possibly be due to ineffective experimental manipulations. However, it appeared that the groups differed in the expected manner. The Stressor task was the most difficult, as inferred by longer reaction times and higher numbers of errors in this group. Reaction times and errors also suggested that the Priming task was much easier than the Stressor task, and yet more difficult than the Control task, which was the easiest of all. Additionally, the reversal trials produced an increase in the number of errors committed in the Stressor and Priming groups, suggesting the reversal trials were more difficult and utilized a larger amount of cognitive resources than the non-reversal trials.

One limitation of this experimental manipulation is that its neurological and cognitive effects have not been established empirically. It is well documented that the Stroop task requires executive functions and utilizes frontal lobe resources. The addition of the reversal learning aspect is similar to the fourth Stroop trial on the Delis-Kaplan Executive Functioning System, which has been well documented to be a test of executive functioning (Delis, Kaplan, & Kramer, 2001). While the experimental manipulation is similar to the Delis-Kaplan task, it is not identical and therefore the generalizability of findings regarding the validity of the Delis-Kaplan task to the current experimental manipulation is not clear. Also, there are no studies examining brain regions involved in performing the Delis-Kaplan task or the current experimental manipulation.

The lack of previous physiological, imaging, or performance based validation of the effect of the experimental manipulation on neurological and cognitive functioning leaves open the possibility that, despite participants' performance on the task matching expectations, the effects on functioning may be different than what was anticipated. Indeed, participants' performance on the IGT in the current study supports this possibility and it is apparent from the results of the current study that the three tasks do not function as Stressor, Priming, and Control tasks regarding performance on the IGT.

One reason for the similarity in performance between the Stressor and Priming groups may be the nature of the process of priming. Priming paradigms have traditionally involved increasing the likelihood of an individual making a certain association in the future, such as thinking “medical doctor” rather than “chemist” when seeing an individual in a white lab coat (for review see Storbeck & Clore, 2008). Other priming paradigms increase the likelihood of certain information (such as positive alcohol outcomes) being used in the future to guide behaviors (such as drinking alcohol) (for reviews see: Shalev, Grimm, & Shaham, 2002; de Wit, 1996). In each case, the likelihood of utilizing certain information over other available information is increased.

The priming target in the current study was not information, but rather a process, which has not been demonstrated before. One major difference between priming information and a cognitive process is the anatomical location of each. Information is typically considered to be stored in long-term memory and to reside anatomically in the posterior of the brain. Cognitive processes are not considered to be stored in memory at all, but rather to be the function of areas in the anterior of the brain. This may be a crucial factor in the ability to observe priming effects concerning cognitive processes and suggests this process may require an alternate paradigm to that of information. This also suggests that rather than a primer and a stressor, the two tasks may have impacted performance similarly due to the fact that each activated and initiated the use of similar brain structures, while the control group did not.

Another factor which could have influenced the results of the current study is the method of determining high and low working memory functioning. The most compelling research investigating the effects of working memory on decision making has utilized a working memory load in order to reduce the amount of working memory resources available for use when completing the decision making task (e.g. Hinson, Jameson, & Whitney, 2002; Dretsch & Tipples, 2008). Other studies have utilized populations with known working memory deficits, such as substance dependent individuals (Bechara & Martin, 2004). The current study sought to extend this literature by examining the performance of two non-clinical, functionally distinct groups based on working memory performance. These groups were developed from an undergraduate population, the same population used in the previous working memory load studies. The hypothesis regarding working memory was developed conceptualizing the effect of working memory on decision making as falling on a continuum, with lower working memory abilities associated with poorer decision making. The results of the current study suggest that the effect of working memory on decision making may not be a continuous relationship. It is possible that a minimum amount of working memory capacity may be necessary to perform decision making tasks adequately, and above that threshold the effect of greater working memory capacity may be minimal. This would explain why a dual task which utilizes the majority of available working memory capacity would impact decision making performance, yet classifying participants as having low or high working memory capacity would not.

This idea is supported by findings demonstrating that individuals with severe amnesia and bilateral hippocampal damage perform poorer on the IGT than matched controls (Gupta et al., 2009; Gutbrod et al., 2006). Gupta and colleagues suggested that long term memory processes (declarative memory) are important for IGT performance, specifically for altering response patterns over time. They suggested that the inability to access information about previous outcomes prevents the refinement of deck preference beyond information contained in the current draw, resulting in participants engaging in a lose-shift response style. This suggests that high or low working memory capacity may not be as important as having the minimal amount of resources available to manipulate information from long term memory. This idea is supported by the lack of differential IGT performance between individuals with significant differences in working memory capacity in the current study. This suggests that measures of cognitive processes independently and under controlled circumstances may not be as indicative of successful IGT performance as determining participants' ability to devote the necessary amount of resources towards the task.

Future Directions

Future studies could offer a better understanding of the effect of working memory on decision making performance by combining the current working memory protocol with a working memory load. This would enable an understanding of both the effect of working memory capacity as well as resource availability on decision making performance and enable an integration of previous findings with the results of the current study. Similarly, determining if there is a minimal level of working memory capacity necessary to perform decision making tasks adequately would aid in understanding decision making in general, and specifically clinical populations with known working memory deficits and impaired decision making abilities.

Future studies could also determine the benefit of measuring the ability to devote an adequate amount of resources to the task at hand in predicting performance on decision making tasks. It is possible that some individuals differ in their ability to utilize the necessary resources in an organized and concerted effort to complete decision making tasks effectively. This 'meta-ability' may be more important than any single ability as decision making is a complex task requiring the organization and integration of many cognitive and neurological systems to complete appropriately.

Future studies may also benefit from utilizing established executive tasks as stressors in order to evaluate the possibility of influencing decision making by stressing the resources of the frontal lobes. Tasks which have been evaluated using a number of different methodologies would be preferable (such as imaging, lesion studies, and comparisons with other cognitive tests), enabling the cognitive and neurological effects of the task to be predicted with a high level of certainty. This would allow the results of the study to be more accurately attributed to the specific effects of the task.

The current study sought to stress the behavioral task of reversal learning, which has been suggested to be mediated by the VMPC (Fellows & Farah, 2005a), which is the same area suggested by Damasio and Bechara (e.g. Damasio, 1996, Bechara, 2005) as being involved in the utilization of Somatic Markers. Recent studies have suggested that the Somatic Marker Hypothesis may not adequately describe performance on the IGT (e.g. Dunn, Dalgleish, & Lawrence, 2006) and that participant's evaluation of gain/loss frequency may better predict performance (Lin et al., 2007). Other studies have also refined an understanding of how situations of uncertainty are evaluated, suggesting the VMPC may evaluate the level of reward available while the Dorsal Medial Prefrontal Cortex may evaluate the level of risk associated with obtaining that reward (Xue et al., 2009). As such, a task which stressed the Dorsal Medial Prefrontal Cortex may be better suited to producing impaired performance on decision making tasks by removing the evaluation of risk, and therefore skewing decision making towards reward.

Overall, the current study failed to demonstrate the hypothesized effect of a reversal learning stressor or primer task on decision making performance. The hypothesized effect of working memory capacity on decision making performance was also not observed. However, the current study does extend the literature concerning decision making and working memory by suggesting that working memory capacity may not related to decision making and that the availability of a minimum amount of working memory resources may be sufficient to perform decision making tasks successfully. These findings may extend to decision making in general, not just on the IGT, and would suggest that the ability to devote the appropriate level of resources towards decision making may be a more important determinant of advantageous decision making than cognitive abilities measured in independently and under controlled conditions.

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Table 1. Descriptive Statistics divided by Working Memory block

	Working Memory			
	Low		High	
Variable	Mean	SD	Mean	SD
Age[1]	19.61	1.31	19.72	1.33
Letter Number Sequencing[2]	11.47	1.95	13.22	2.17
Spatial Span[2]	14.49	1.63	21.32	1.56
IGT Algorithm[2]				
Block 1	-2.29	8.23	-2.79	7.16
Block 2	1.75	7.59	2.48	8.33
Block 3	3.20	7.99	3.75	9.37
Block 4	2.02	10.18	3.07	9.80
IGT Total Money[2]				
Block 1	2629.90	713.20	2593.53	628.62
Block 2	1908.82	634.64	1911.47	634.61
Block 3	1581.37	713.88	1803.53	623.36
Block 4	1850.98	799.78	1834.41	684.07
BIS/BAS[1]				
Drive	8.06	2.39	8.54	1.90
Fun	6.90	2.00	7.10	2.37
Reward	6.69	1.88	7.04	1.65
BIS	13.44	3.60	14.28	3.78
SPSRQ[1]				
Punishment	11.66	3.97	11.38	4.60
Reward	12.52	3.81	13.48	3.65
CMHS[1]	19.23	6.77	21.64	6.99

[1]n = 134, [2]n=136

Table 2. Descriptive Statistics divided by Group

	Reversal Learning Group		
Variable	Stressor	Priming	Control
Age[1]	19.60 (1.33)	19.68 (1.27)	19.74 (1.37)
Letter Number Sequencing[2]	12.19 (2.31)	13.27 (2.31)	12.34 (2.03)
Spatial Span[2]	18.63 (3.55)	18.68 (4.00)	18.96 (3.58)
IGT Algorithm[2]			
Block 1	-1.04 (8.89)	-4.41 (7.21)	-2.62 (6.01)
Block 2	1.29 (8.62)	3.49 (8.16)	2.02 (7.32)
Block 3	4.54 (7.84)	4.22 (7.86)	1.94 (10.46)
Block 4	3.50 (8.99)	3.00 (10.55)	1.55 (10.36)
IGT Total Money[2]			
Block 1	2643.23 (608.03)	2460.98 (719.59)	2697.87 (646.97)
Block 2	2051.04 (611.55)	1831.10 (595.94)	1836.17 (671.12)
Block 3	1779.17 (638.80)	1695.73 (742.46)	1681.38 (629.06)
Block 4	1790.63 (698.43)	1934.76 (730.49)	1809.57 (758.98)
BIS/BAS[1]			
Drive	7.52 (2.14)	8.49 (1.95)	9.04 (2.08)
Fun	6.96 (2.07)	7.15 (2.23)	6.92 (2.56)
Reward	6.69 (1.80)	7.24 (1.81)	6.89 (1.61)
BIS	14.34 (4.03)	14.00 (3.47)	13.82 (3.71)
SPSRQ[1]			
Punishment	10.84 (4.61)	12.15 (3.81)	11.34 (4.84)
Reward	13.54 (3.90)	12.63 (3.89)	13.24 (3.59)
CMHS[1]	20.45 (7.79)	22.45 (7.22)	20.47 (6.42)

[1]n = 134, [2]n=136

Table 3. Average number of draws from each deck during each block.

	Block1	Block 2	Block 3	Block 4
Deck 1	5.01 (2.31)	3.86 (2.15)	2.97 (2.12)	2.58 (2.04)
Deck 2	8.79 (3.84)	7.54 (3.25)	7.76 (3.91)	8.58 (4.66)
Deck 3	5.79 (2.33)	6.49 (3.20)	6.84 (3.77)	6.96 (4.12)
Deck4	5.40 (2.71)	7.12 (3.81)	7.43 (4.05)	6.88 (4.09)

n = 136

Table 4. Correlations between Personality and IGT Algorithm

	IGT Block				
	1	2	3	4	Total
BAS Drive	-.080	.022	.090	.005	.017
BAS Fun	-.018	-.118	.006	-.180*	-.119
BAS Reward	-.060	.084	-.075	-.066	-.046
BIS	-.036	-.088	.000	-.006	-.044
SPSRQ Reward	-.136	-.108	-.028	.071	.087
SPSRQ Punishment	.007	.093	.064	.022	-.081
CMHS	-.004	-.048	.038	.008	.000

*=*p*=.05, **=*p*=.01, n = 134

Table 5. Correlations between Personality and IGT Total Money.

	IGT Block			
	1	2	3	4
BAS Drive	-.024	-.081	.096	.138
BAS Fun	-.010	-.038	-.060	.004
BAS Reward	-.035	-.024	.041	.016
BIS	.011	-.091	-.084	-.034
SPSRQ Reward	-.056	-.089	-.067	-.004
SPSRQ Punishment	-.078	.057	.072	.039
CMHS	.056	-.008	-.004	.000

*=*p*=.05, **=*p*=.01, n = 134

Table 6. IGT Performance regressed onto Personality Variables.

Predicted Variable		R^2	ΔR^2
Algorithm 25	Step 1	.037	
	Step 2	.072	.035
Algorithm 50	Step 1	.018	
	Step 2	.093	.075
Algorithm 75	Step 1	.016	
	Step 2	.058	.042
Algorithm 100	Step 1	.008	
	Step 2	.067	.059
Total Money 25	Step 1	.030	
	Step 2	.041	.011
Total Money 50	Step 1	.032	
	Step 2	.072	.039
Total Money 75	Step 1	.028	
	Step 2	.076	.048
Total Money 100	Step 1	.008	
	Step 2	.035	.027

*=p=.05, **=p=.01, n = 134

Figure 1. Response time in milliseconds during the modified Stroop Task presented by RLG.

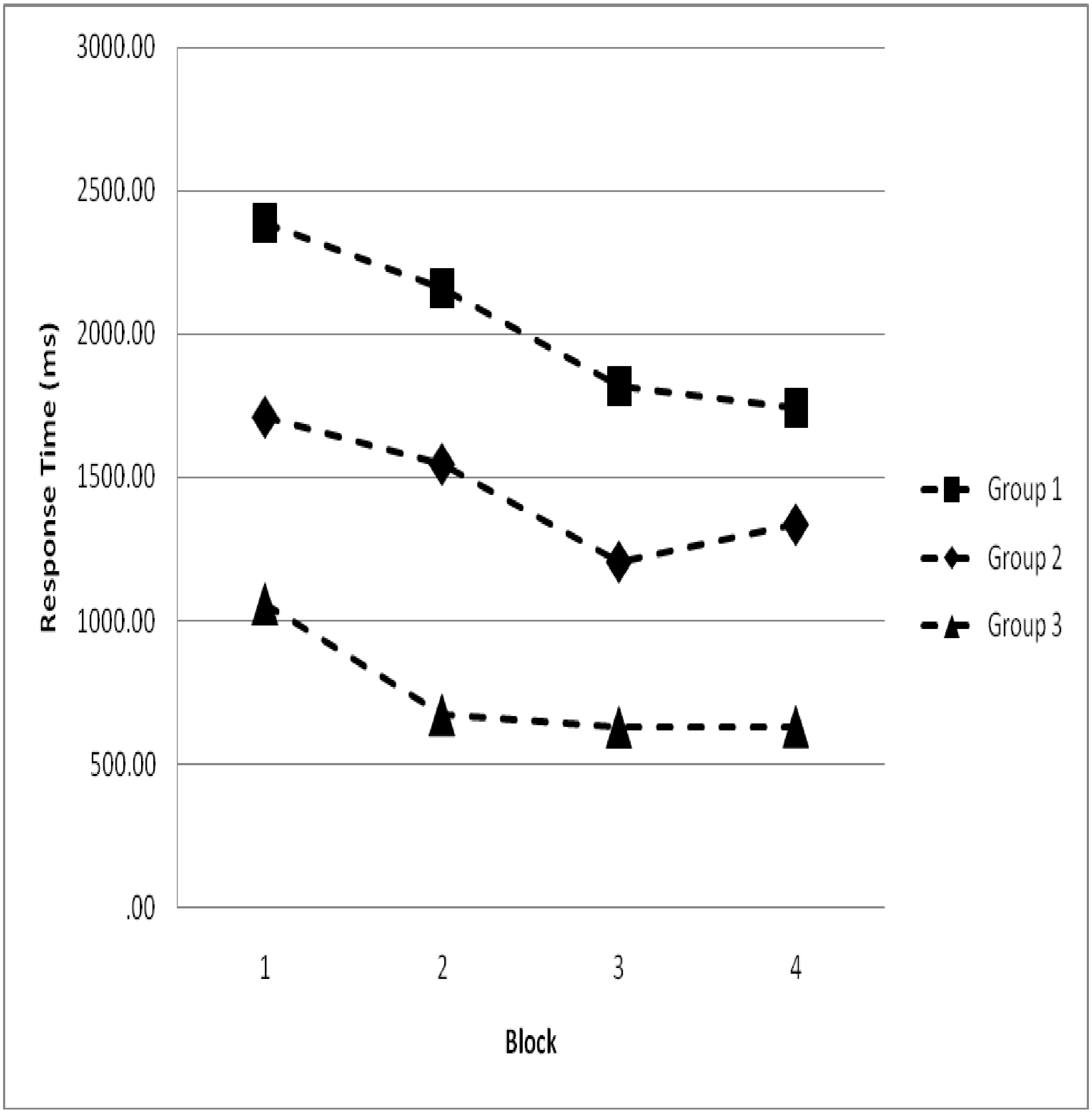


Figure 2. Errors committed during the modified Stroop Task presented by RLG.

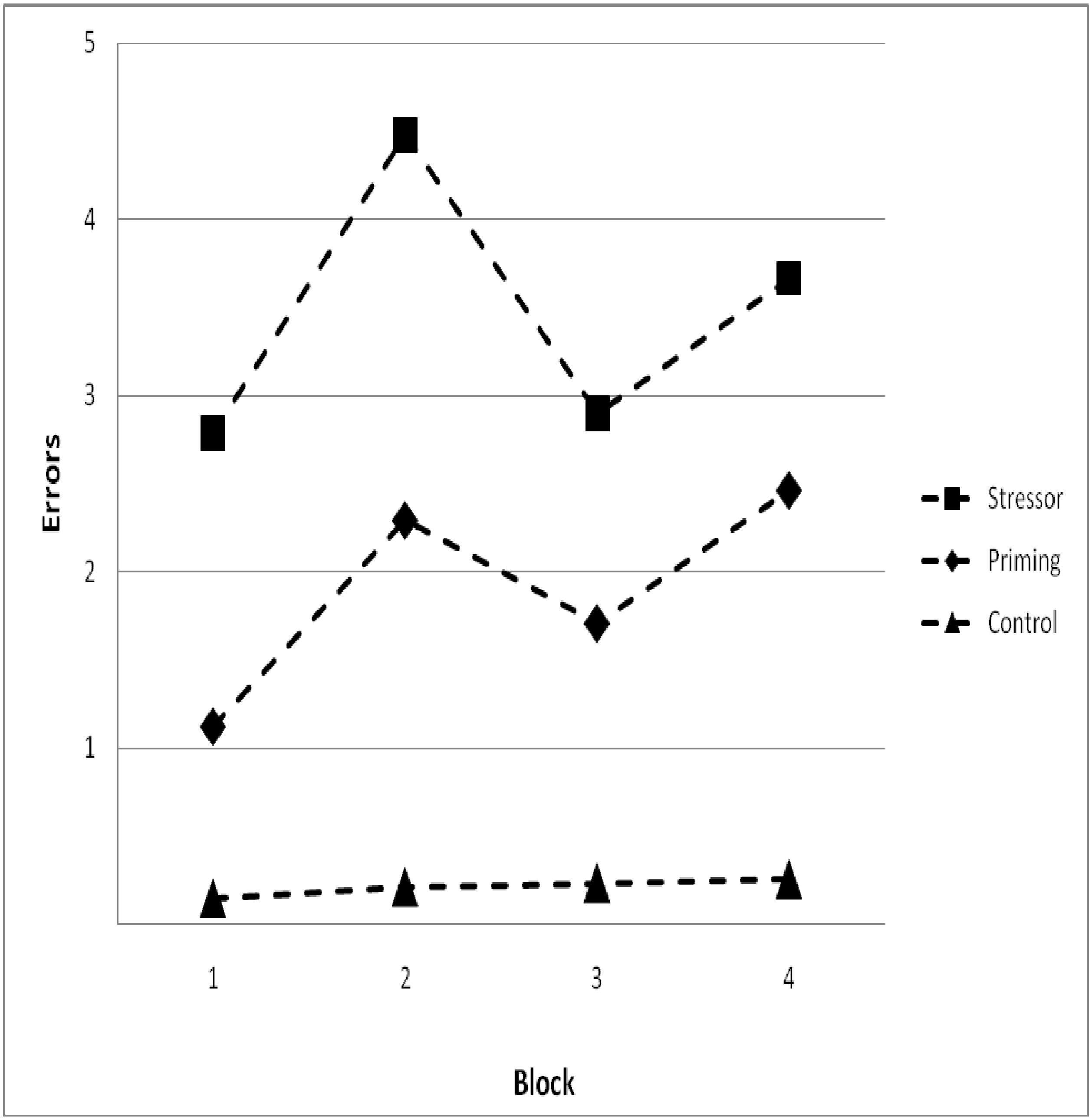


Figure 3. IGT Algorithm at each time point presented by WM Block and RLG.

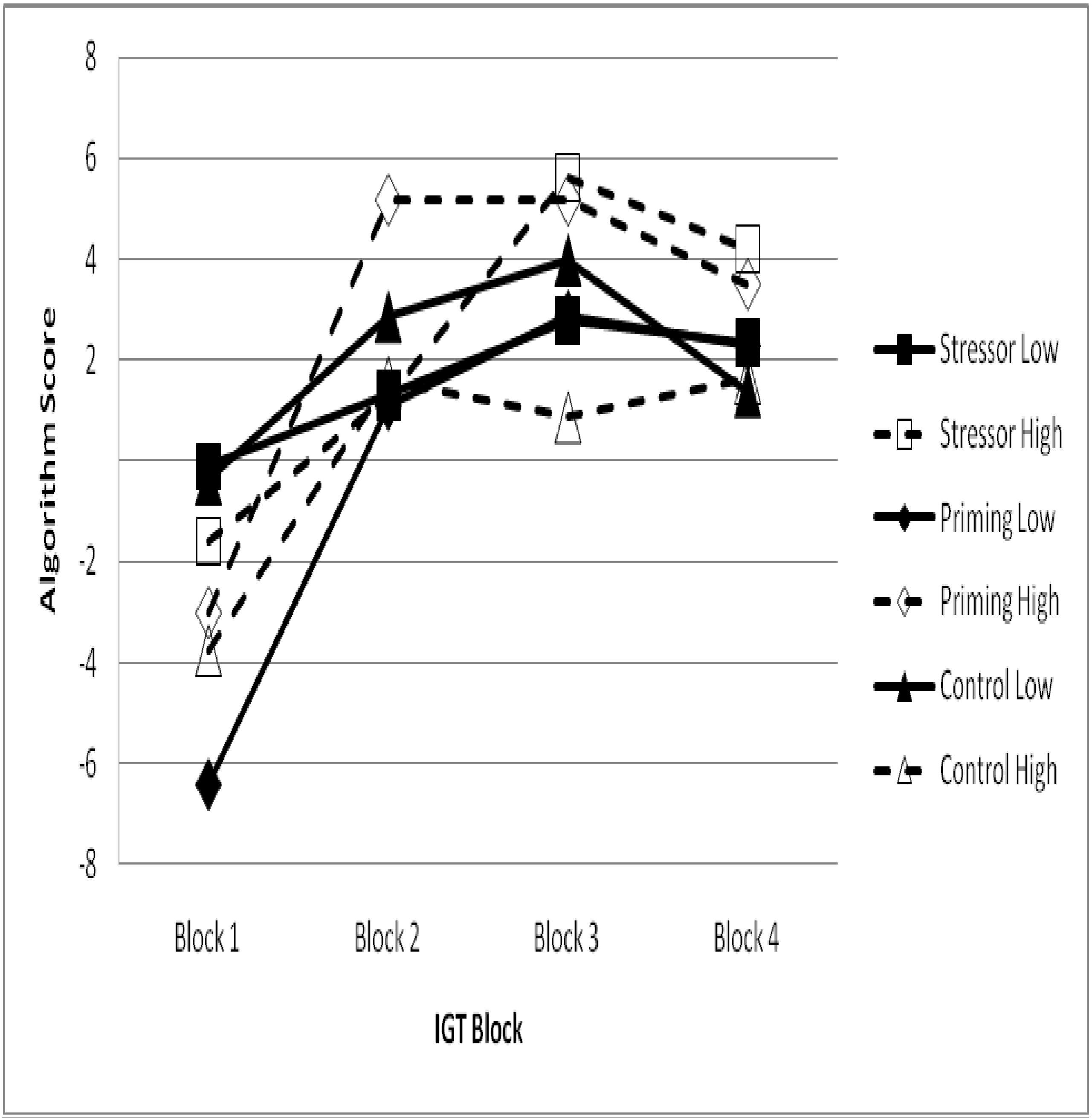


Figure 4. Total Money at each time point presented by WM Block and RLG.

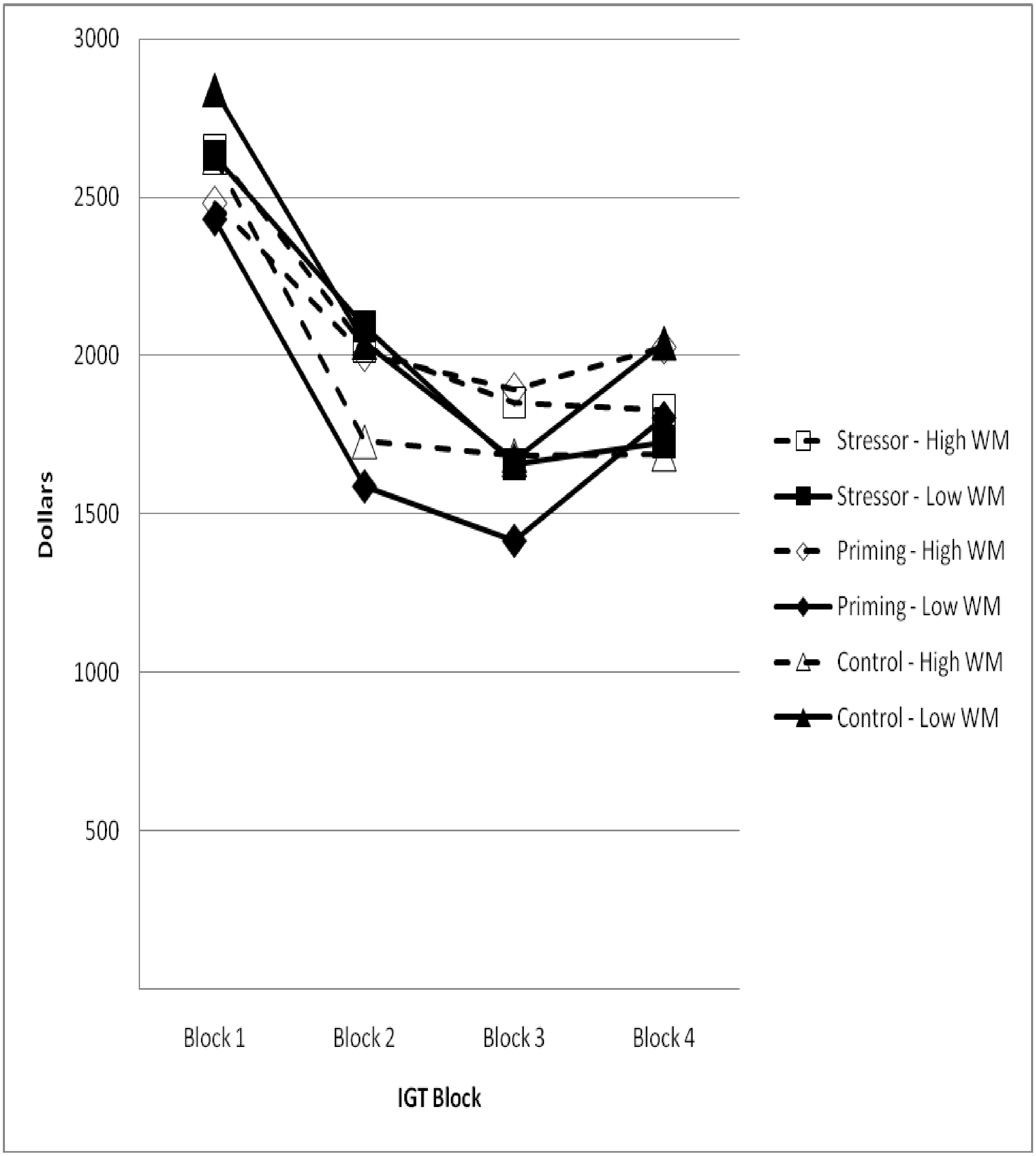


Figure 5. WM by RLG interaction for the analysis of Total Money on the IGT.

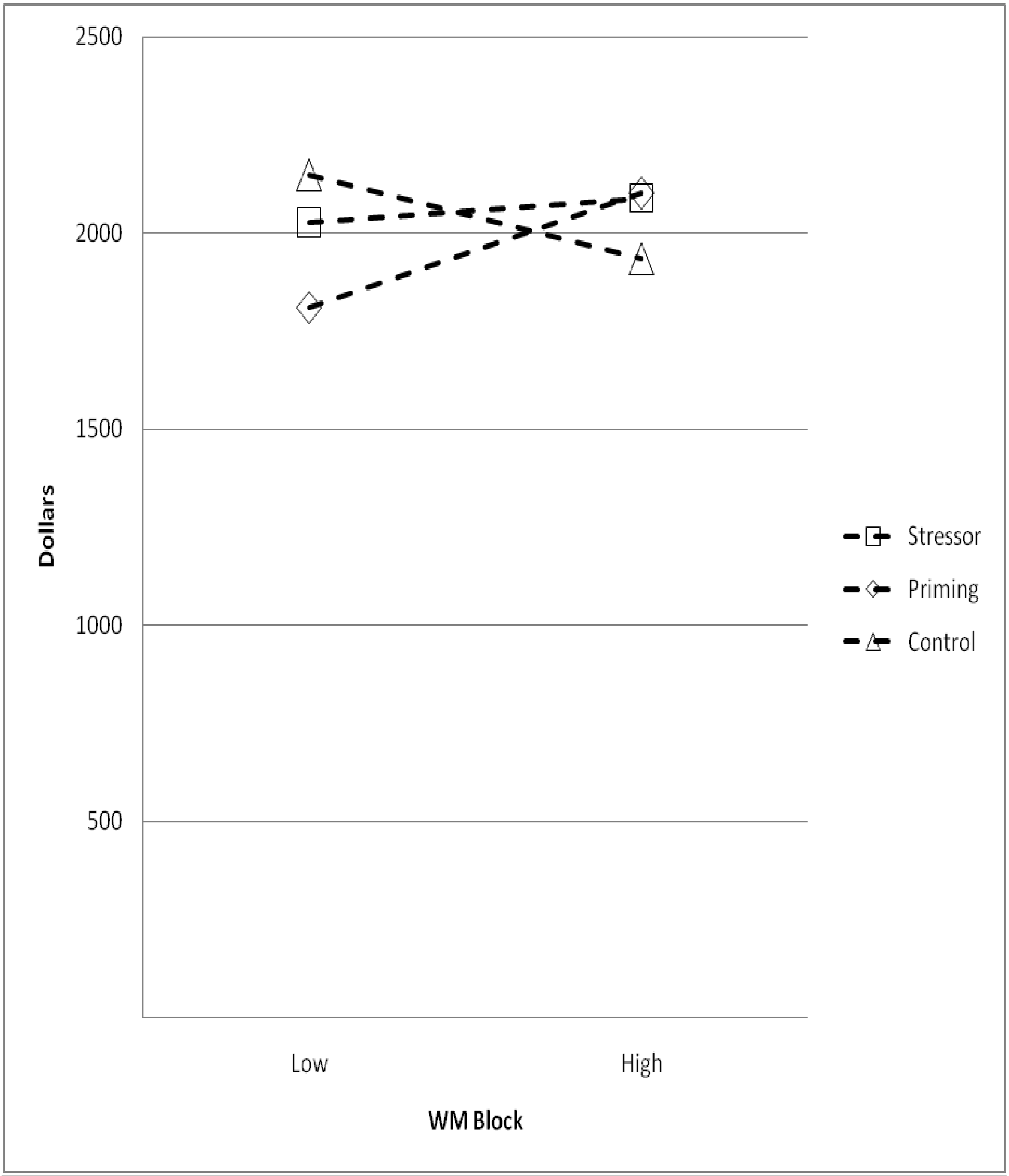


Figure 6. IGT Algorithm performance by RLG.

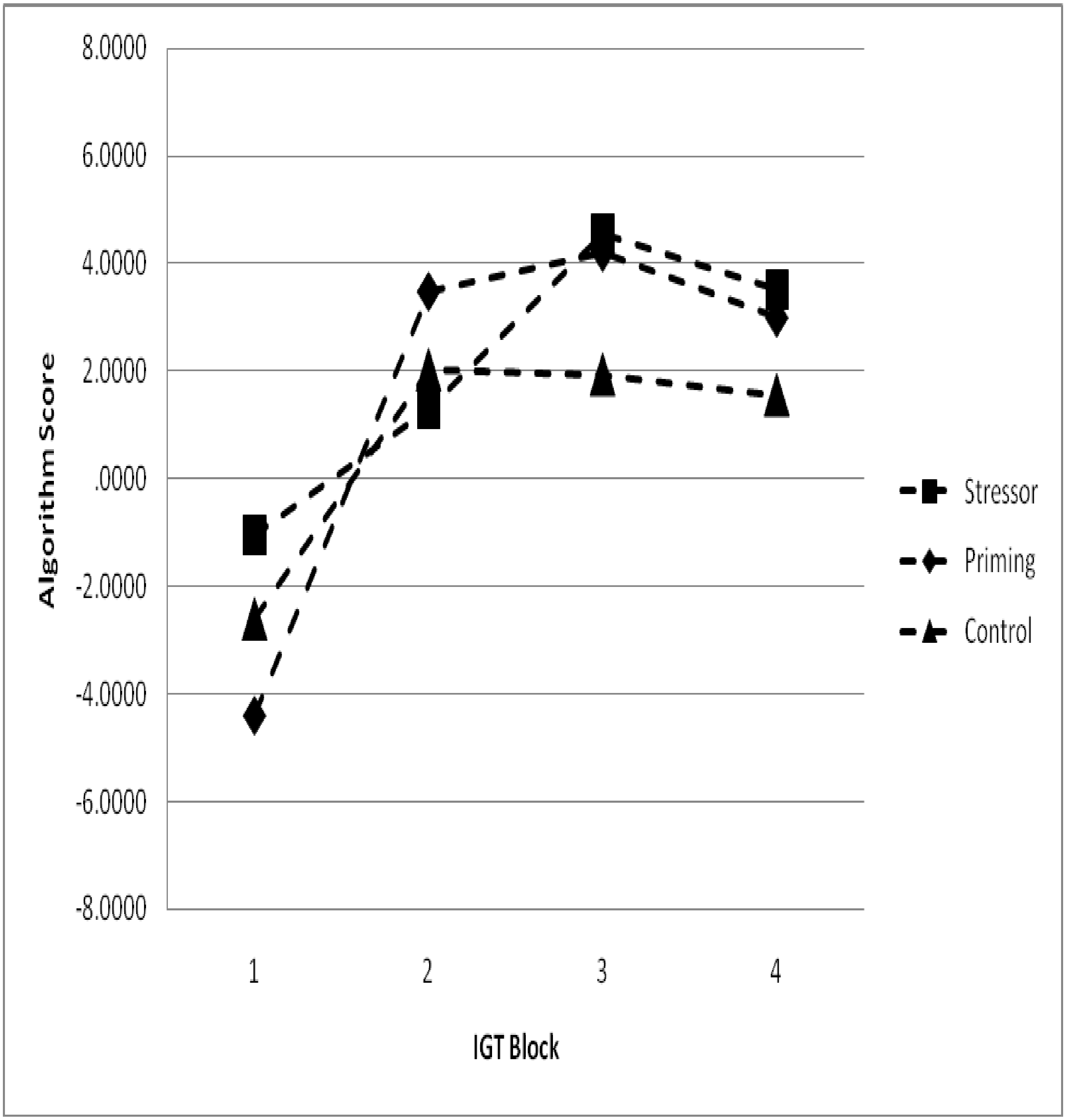
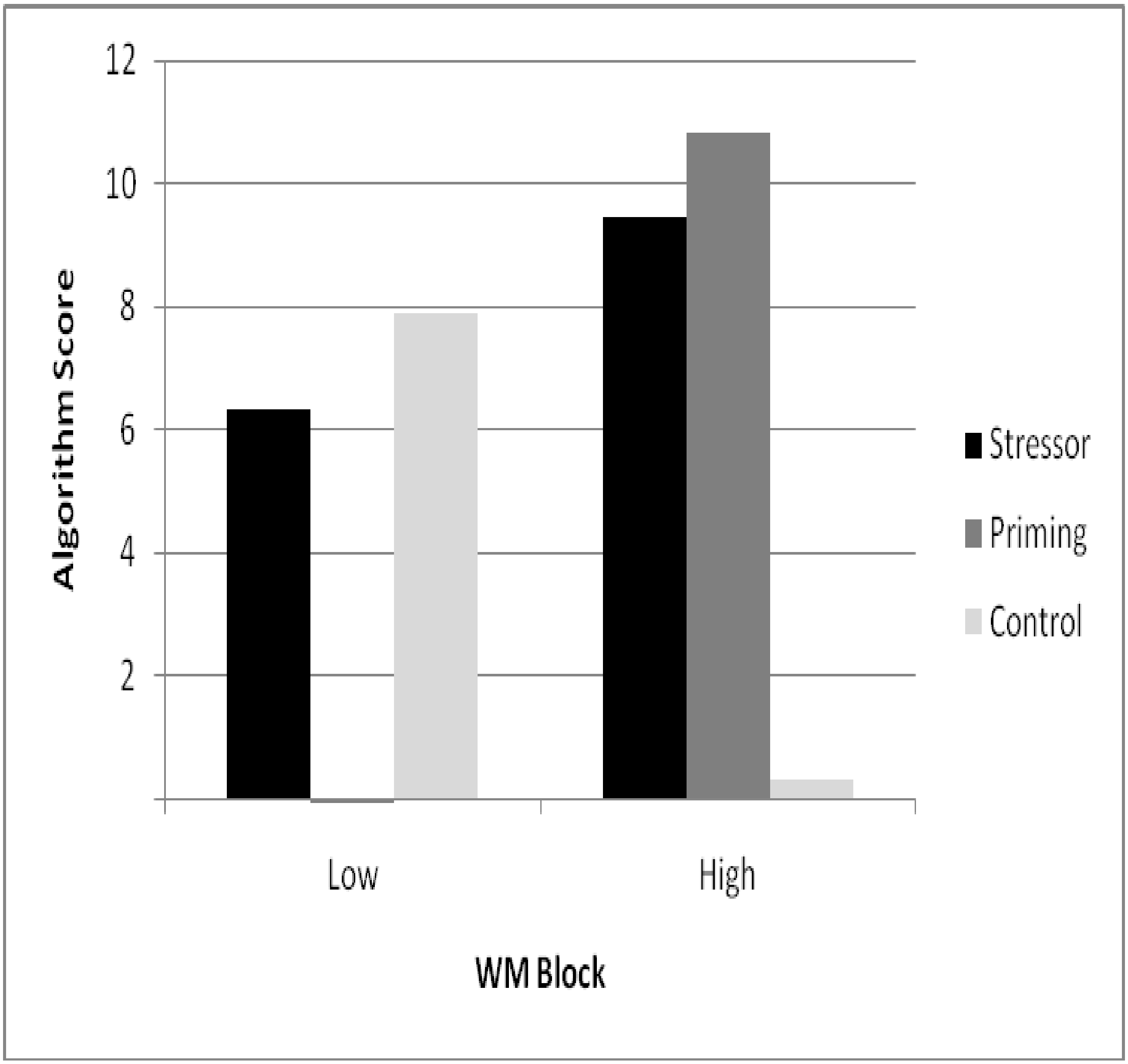


Figure 7. IGT Algorithm over the 100 card administration by RLG and WM.



Appendix A

BIS/BAS

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

1. A person's family is the most important thing in life.
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
3. I go out of my way to get things I want.
4. When I'm doing well at something I love to keep at it.
5. I'm always willing to try something new if I think it will be fun.
6. How I dress is important to me.
7. When I get something I want, I feel excited and energized.
8. Criticism or scolding hurts me quite a bit.
9. When I want something I usually go all-out to get it.
10. I will often do things for no other reason than that they might be fun.
11. It's hard for me to find the time to do things such as get a haircut.
12. If I see a chance to get something I want I move on it right away.
13. I feel pretty worried or upset when I think or know somebody is angry at me.
14. When I see an opportunity for something I like I get excited right away.
15. I often act on the spur of the moment.
16. If I think something unpleasant is going to happen I usually get pretty "worked up."
17. I often wonder why people act the way they do.
18. When good things happen to me, it affects me strongly.
19. I feel worried when I think I have done poorly at something important.
20. I crave excitement and new sensations.
21. When I go after something I use a "no holds barred" approach.
22. I have very few fears compared to my friends.
23. It would excite me to win a contest.
24. I worry about making mistakes.

Appendix B

PANAS – M

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now, that is, at the present moment. Use the following scale to record your answers.

1	2	3	4	5
very slightly	a little	moderately	quite a bit	extremely

____interested	____irritable
____distressed	____alert
____excited	____ashamed
____upset	____inspired
____strong	____nervous
____guilty	____determined
____scared	____attentive
____hostile	____jittery
____enthusiastic	____active
____proud	____afraid

Appendix C

Sensitivity to Punishment and Sensitivity to Reward Questionnaire

Please respond with a yes or no to the following questions about how you generally behave or think.

1. Do you often refrain from doing something because you are afraid of it being illegal?
2. Does the good prospect of obtaining money motivate you strongly to do some things?
3. Do you prefer not to ask for something when you are not sure you will obtain it?
4. Are you frequently encouraged to act by the possibility of being valued in your work, in your studies, with your friends or with your family?
5. Are you often afraid of new or unexpected situations?
6. Do you often meet people that you find physically attractive?
7. Is it difficult for you to telephone someone you do not know?
8. Do you like to take some drugs because of the pleasure you get from them?
9. Do you often renounce your rights when you know you can avoid a quarrel with a person or organization?
10. Do you often do things to be praised?
11. As a child, were you troubled by punishments at home or in school?
12. Do you like being the center of attention at a party or social gathering?
13. In tasks that you are not prepared for, do you attach a great importance to the possibility of failure?
14. Do you spend a lot of your time on obtaining a good image?
15. Are you easily discouraged in difficult situations?
16. Do you need people to show their affection for you all the time?
17. Are you a shy person?
18. When you are in a group, do you try to make your opinions the most intelligent or the funniest?
19. Whenever possible, do you avoid demonstrating your skills for fear of being embarrassed?
20. Do you often take the opportunity to pick up people you find attractive?
21. When you are with a group do you have difficulties selecting a good topic to talk about?
22. As a child, did you do a lot of things to get people's approval?
23. Is it often difficult for you to fall asleep when you think about things you have done or must do?
24. Does the possibility of social advancement move you to action, even if this involves not playing fair?
25. Do you think a lot before complaining in a restaurant if your meal is not well prepared?
26. Do you generally give preference to those activities that imply an immediate gain?
27. Would you be bothered if you had to return to a store when you noticed you were given the wrong change?
28. Do you often have trouble resisting the temptation of doing forbidden things?
29. Whenever you can, do you avoid going to unknown places?
30. Do you like to compete and do everything you can to win?

31. Are you often worried by things that you said or did?
32. Is it easy for you to associate tastes and smells to very pleasant events?
33. Would it be difficult for you to ask your boss for a raise (salary increase)?
34. Are there a large number of objects or sensations that remind you of pleasant events?
35. Do you generally try to avoid speaking in public?
36. When you start to play with a slot machine, is it often difficult for you to stop?
37. Do you, on a regular basis, think that you could do more things if it was not for your insecurity or fear?
38. Do you sometimes do things for quick gains?
39. Comparing yourself to people you know, are you afraid of many things?
40. Does your attention easily stray from your work in the presence of an attractive stranger?
41. Do you often find yourself worrying about things to the extent that performance in intellectual abilities is impaired?
42. Are you interested in money to the point of being able to do risky jobs?
43. Do you often refrain from doing something you like in order not to be rejected or disapproved of by others?
44. Do you like to put competitive ingredients in all of your activities?
45. Generally, do you pay more attention to threats than to pleasant events?
46. Would you like to be a socially powerful person?
47. Do you often refrain from doing something because of your fear of being embarrassed?
48. Do you like displaying your physical abilities even though this may involve danger?

Appendix D

Cook-Medley Hostility Scale

Directions: If a statement is true or mostly true, as pertaining to you, circle the letter T. If a statement is false, or usually not true about you, circle the letter F. Please give a response to every statement.

1. When I take a new job, I like to be tipped off on who should be gotten next to.	T	F
2. When someone does me wrong, I feel I should pay him back if I can, just for the principle of the thing.	T	F
3. I prefer to pass by school friends, or people I know but have not seen for a long time, unless they speak to me first.	T	F
4. I often had to take orders from someone who did not know as much as I did.	T	F
5. I think a great many people exaggerate their misfortunes in order to gain the sympathy and help of others.	T	F
6. It takes a lot of argument to convince most people of the truth.	T	F
7. I think most people lie to get ahead.	T	F
8. Someone has it in for me.	T	F
9. Most people are honest chiefly through the fear of getting caught.	T	F
10. Most people will use somewhat unfair means to gain profit or an advantage, rather than lose it.	T	F
11. I commonly wonder what hidden reason another person may have for doing something nice for me.	T	F
12. It makes me impatient to have people ask my advice or otherwise interrupt me when I am working on something important.	T	F
13. I feel that I have often been punished without cause.	T	F
14. I am against giving money to beggars.	T	F
15. Some of my family have habits that bother me very much	T	F
16. My relatives are nearly all in sympathy with me.	T	F
17. My way of doing things is apt to be misunderstood by others.	T	F
18. I don’t blame anyone for trying to grab everything they can get in this world.	T	F
19. No one cares what happens to you.	T	F
20. I can be friendly with most people who do things I consider wrong.	T	F
21. It is safer to trust nobody.	T	F
22. I do not blame a person for taking advantage of someone who lays himself open to it.	T	F
23. I have often felt that strangers were looking at me critically.	T	F
24. Most people make friends because friends are likely to be useful to them.	T	F
25. I am sure I am being talked about.	T	F
26. I am likely not to speak to people until they speak to me.	T	F
27. Most people inwardly dislike putting themselves out to help other people.	T	F
28. I tend to be on guard with people who are somewhat more friendly than I had expected.	T	F
29. I have sometimes stayed away from another person because I feared doing or saying something that I might regret afterwards.	T	F

30. People often disappoint me	T	F
31. I like to keep people guessing what I'm going to do next.	T	F
32. I frequently ask people for advice.	T	F
33. I am not easily angered.	T	F
34. I have often met with people who are supposed to be experts who were no better at it than I.	T	F
35. It makes me think of failure when I hear of the success of someone I know well.	T	F
36. I would certainly enjoy beating a crook at his own games.	T	F
37. I have at times had to be rough with people who were rude or annoying.	T	F
38. People generally demand more respect for their own rights than they are willing to allow for others.	T	F
39. There are certain people whom I dislike so much I am inwardly pleased when they are catching it for something they have done.	T	F
40. I am often inclined to go out of my way to win a point with someone who has opposed me.	T	F
41. I am quite often not in on the gossip and talk of the group I belong to.	T	F
42. The man who had the most to do with me when I was a child (such as my father, step-father, etc.) was very strict with me.	T	F
43. I have often found people jealous of my good ideas just because they had not thought of them first.	T	F
44. When a man is with a woman, he is usually thinking of things related to her sex.	T	F
45. I do not try to cover up my poor opinion or pity of a person so that he won't know how I feel.	T	F
46. I have frequently worked under people who seem to have things arranged so that they get credit for good work, but are able to pass off mistakes to those under them.	T	F
47. I strongly defend my own opinions as a rule.	T	F
48. People can pretty easily change me even though I thought that my mind was made up on a subject.	T	F
49. Sometimes I am sure that other people can tell what I'm thinking.	T	F
50. A large number of people are guilty of bad sexual conduct.	T	F

Appendix E

Demographic Information and Medical History

PID ____/____ /____ DATE: Month______ Day______ Year______

1	Do you have any history of congenital or developmental problems?	Yes	No
2	Do you have any history of learning disabilities or special education?	Yes	No
3	Do you have any history of hypoglycemia (low blood glucose)?	Yes	No
4	Do you have any history of hyperglycemia (diabetes)?	Yes	No
5	Are you experiencing blood glucose problems at present?	Yes	No
6	Do you have a history of hypertension? (high blood pressure)	Yes	No
7	Do you have any history of hypotension? (low blood pressure)	Yes	No
8	Do you have any history of hyperthyroidism?	Yes	No
9	Do you have any history of hypothyroidism?	Yes	No
10	Have you ever suffered a head injury resulting in a hospital stay longer than 24 hours?	Yes	No
11	Have you ever been knocked out or rendered unconscious (more than 5 minutes)	Yes	No
12	Have you ever suffered "black-out" or fainting spells?	Yes	No
13	Do you have a history of other neurological disorders? (e.g. stroke or brain tumor)	Yes	No
14	Have you ever received psychiatric/psychological care or counseling	Yes	No
15	Have you ever been hospitalized in a psychiatric facility/hospital?	Yes	No
16	Have you ever been diagnosed with a psychiatric/psychological disorder?	Yes	No
17	Have you ever been administered any neuropsychological tests or measures?	Yes	No
18	Do you have any history of heart disease?	Yes	No
19	Do you have any history of pancreatic disease?	Yes	No
20	Are you currently taking any prescription blood thinning medications?	Yes	No
21	Do you have any uncorrected visual or hearing impairments?	Yes	No
22	Are you able to read write and speak English effectively?	Yes	No
23	Are you taking any of the following medications: antidepressant, antianxiety, or antipsychotic?	Yes	No
24	Are you taking allergy or cold medicine?	Yes	No
25	Do you frequently experience migraine headaches?	Yes	No
26	Do you have a history of chronic earache that lasted more than a month?	Yes	No
27	Do you often experience pressure in the inner ear?	Yes	No
28	Do you frequently hear a persistent ringing, buzzing, or hissing sound?	Yes	No
29	Have you ever been diagnosed with any of the following vestibular disorders: Orthostatic dysregulation, Meniere's Disease, Cogan's Syndrome, Labyrinthine Infarct, or Neurolabyrinthitis?	Yes	No

30	Do you have a history of panic attacks or Agoraphobia?	Yes	No
31	What is your age?		
32	What is your weight?		
33	What is your height?		
34	What is your sex?		
35	What is your Ethnicity/Race?		
35	What is your current GPA at Virginia Tech?		
36	What year are you at Virginia Tech?		