IMPULSIVITY AND REWARD SENSITIVITY: ATTENTIONAL AND EMOTIONAL FACTORS UNDERLYING STIMULUS-REWARD LEARNING

by

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A thesis submitted to the Department of Psychology

In conformity with the requirements for

the degree of Master of Science

Queen's University

Kingston, Ontario, Canada

(February, 2010)

Abstract

Increased impulsivity and alterations in reward sensitivity co-occur in many psychiatric disorders. Moreover, individuals reporting more impulsive traits are less efficient in learning stimulus-reward associations. This suggests that impulsivity and reward sensitivity may be linked, consistent with evidence that the orbital frontal cortex (OFC) is implicated in both processes. This study examined the relationship between impulsive traits, assessed by the Barratt Impulsiveness Scale (BIS) and the Eysenck (EIQ), and performance on three behavioral tasks that measure impulsivity and reward sensitivity. The tasks included a Conditioned Pattern Preference (CPP) task, which measures the preference for abstract visual cues as an index of implicit emotional learning, a Probabilistic Reversal Learning (PRL) task that assessed the ability to alter behaviour when reward contingencies change and an Emotional Stroop task which assessed attentional control in response to emotionally salient stimuli. This study provided novel information on the relationship between processes that mediate impulsivity and reward sensitivity. In brief, subjects that were considered to have some explicit knowledge of experimental conditions showed a higher preference formation for the pattern paired with the reward on 90% of the conditioning trials. Although there was no overall effect of impulsivity, the medium impulsive group displayed the strongest preference formation (highest score for the 90% pattern and lowest score for the 10% pattern) compared to the low and high groups. Furthermore, there was an overall effect of Word Category in that participants made more errors for the emotional words (positive and negative) than the neutral words. There was no overall effect of Impulsivity on

Stroop performance in this sample. Finally, for the PRL task more participants in the high impulsive group did not meet criterion for the Acquisition stage while more low impulsive subjects did not meet reversal criterion. Furthermore, high impulsive subjects made more overall errors in the Acquisition stage but not Reversal stage. In brief, low and high impulsive subjects performed sub-optimally on the CPP and PRL tasks but not on the Stroop task. This pattern reflects an inverted-U shaped relationship of the effects of impulsivity on associative learning.

Acknowledgements

I am extremely grateful and fortunate to have had Cella as a mentor. Her support, knowledge, understanding and (what can only be construed as) limitless patience have taught me to be a better student researcher. She has brought out the best in me and has helped me focus on improving my weaknesses. Further, I would like to acknowledge the patience and understanding of my committee members (Dr. Ingrid Johnsrude and Dr. Richard Beninger) concerning my late submission. I feel very fortunate to be learning from such exceptional PI's; such success is humbling and undoubtedly inspiring. Next, I greatly appreciate the input of Dr. Leandre R. Fabrigar for taking the time to answer my analysis questions over the course of my write up. I am also very thankful to Davin Carlson for his invaluable assistance in programming the Reversal Learning task. I must also bring special attention to Nate Sklair's generous support in helping/teaching me to program the Stroop task. His help has given me the confidence to attempt more difficult tasks and for this I believe he deserves credit. Many thanks to Sheila Dillon-Leitch for helping me with various tasks, especially for her help with subject recruitment. In the past couple of years, I have had exceptional support from within the Psychology department: Dianne Flint, Marie Tooley and Jane Dauncey. Without them, I would have missed many more deadlines.

I am thankful to my labmates Scott Hayton, Megan Mahoney and Sylvia Magrys for making Humphrey Hall a pleasant building to work in. It has been great working alongside like-minded people. I cannot ignore the countless coffee sessions with friends (Christina Maniates, Diala Habib, Emily Hawken and Peter Gagolewicz) who helped make Kingston a welcoming place to live. They have contributed extensively to my growing caffeine addiction but that is a small price to pay for the invaluable support and laughter they have provided. Christina Maniates is particularly credited with metaphorically kicking me in the head every time I entertained the idea of inadequacy.

Finally, I would like to extend a warm appreciation to my family. I will start by thanking my loving parents who would rather I get married and have babies than pursue a career away from them. Nevertheless, they are proud that my work is incomprehensible to them; I am glad that they believe I have surpassed them, although I have a lot left to accomplish before I can believe that myself. I have to thank my mother for calling me every day (sometimes twice a day, overbearingly) instead of moving in with me like she wishes. It took a lot of self-restraint and I appreciate it. Likewise, I have to thank my father for not calling me everyday even though I know he has missed me very much. I have to thank my stylish 87 year old grandfather for encouraging me to pursue what I want although he thinks I am pursuing medicine no matter how many times I have corrected him. My siblings Demetre, Costa and Angeliki have been nothing but supportive these past couple of years. They have been especially helpful in keeping our mother from moving in with me. I would like to draw special attention to my brother Demetre for his permission in taking ‘his’ car, which gave me the freedom of spontaneous travel. There is no better gift than that.

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LIST OF ABBREVIATIONS

5-HT – Serotonin

ADHD – Attention-Deficit Hyperactivity Disorder

BAS – Behavioural Approach System

BIS-11 – Barratt Impulsiveness Scale

BIS – Behavioural Inhibition System

BIS/BAS – Behavioural Inhibition/Behavioural Activation Systems scale

CPP – Conditioned Pattern Preference

DA – Dopamine

DPD – Delay and Probability Discounting

EIQ - Eysenck Impulsivity Questionnaire

IGT – Iowa Gambling task

MMD – Manic Depressive Disorder

NA – Noradrenaline

OFC – Orbito frontal cortex

PG – Pathological gambling

PFC – Prefrontal cortex

PRL – Probabilistic Reversal Learning

RST – Reinforcement Sensitivity Theory

RT – Reaction time

SPSRQ – Sensitivity to Punishment and Sensitivity to Reward Questionnaire

WM – Working memory

Chapter 1

Introduction

A number of psychiatric disorders, including pathological gambling, substance abuse and attention-deficit hyperactivity disorder (ADHD) are characterized by high levels of impulsivity and altered reward sensitivity (Rogers & Robbins, 2001; Seidman, Biederman, Weber, Hatch, & Faraone, 1998). Pathological gambling (PG) is a serious psychiatric disorder that afflicts 1-3% of the general population and is classified among impulse control disorders (ICD) in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (Stucki & Rihs-Middel, 2007). Substance abuse is characterized by a significant impairment or distress caused by a maladaptive pattern of substance use. Used interchangeably with the term drug addiction, substance abuse can be defined simply as the continued use of substances in the face of negative consequences. This cognitive aspect of drug addiction is not well studied, despite evidence that disruption of cognitive control is the main characteristic of drug addiction (Everitt, Hutcheson, Ersche, Pelloux, Dalley, & Robbins). ADHD, often diagnosed in childhood, affects 3-9% of children (Szatmari, Offord, Siegel, & Finlayson, 1990). The disorder is characterized by a lack of cognitive control and includes the symptoms of attentional difficulties, hyperactivity, impulsive decision-making and dysregulated emotional responses. These statistics make it clear that the behavioural trait of impulsivity is a marked factor in many psychiatric disorders.

The study of ADHD may provide insight into substance abuse as the two disorders are related (Levin & Klever, 1995). When the symptoms of ADHD are combined with those of substance abuse, the severity of both disorders increases (Levin, Evans, McDowell, Brooks, & Nunes, 2002). Moreover, ADHD in adults is associated with poor treatment compliance and relapse to substance use in a cocaine-dependent population (Caroll & Rounsaville, 1993). Individuals with a childhood history of ADHD who also used cocaine started taking the drug at an earlier age, used it more frequently, consumed greater amounts of the drug, and have a greater number of drug exposures than individuals without childhood histories of ADHD (Carroll & Rounsaville, 1993). Some aspect of ADHD, therefore, such as trait impulsivity may be a risk factor for substance abuse.

Impulsivity

The construct of impulsivity is multidimentional and can be subdivided into three broad categories: a) disinhibition or the inability to withhold a motor response; b) preference for a small immediate reward over a large delayed reward (cognitive impulsivity); and c) perseveration of a response that is unrewarded or punished (Moeller, Barratt, Dougherty, Schmitz & Swann, 2001).

It is not clear whether self-report and laboratory measures assess the same features of impulsivity. There are two commonly employed self-report measures of impulsivity: the Barratt Impulsiveness Scale (BIS-11) and the Eysenck EIQ (Eysenck, 1985; Patton, Stanford and Barratt, 1995). The BIS-11 questionnaire is a 30 -item questionnaire with motor, cognitive and self-control subscales. The EIQ measures risky behaviour (‘venturesome’) as well as emotional aspects of impulsivity (‘empathy’). Both the BIS-11 and EIQ use visual analog scales to evaluate self-reported tendencies to engage in impulsive behaviours such as ‘acting without considering the consequences’ and are known to be highly correlated (Luengo, Carrillo-de-la-pena, & Otero, 1991).

Laboratory measures of impulsivity also encompass a wide range of impulsive behaviours such as, motor, cognitive and self-control. The most commonly used paradigms are: the Delay and Probability Discounting (DPD) tasks, the Probabilistic Reversal Learning (PRL) task, the Stop task, the Go/No-go task, and the Iowa Gambling task (IGT).

The DPD tasks measure the discounting or devaluation of rewards by delay and probability (uncertainty). In these, subjects have the opportunity to choose between different amounts of money/rewards, which are made available after varying delays or probabilities. These tasks measure the value of immediate versus delayed rewards and as such tap into aspects of self-control (Richards, Mitchell, DeWit, & Seiden, 1997).
In PRL tasks, subjects have to choose between two stimuli (an advantageous one and a disadvantageous one). Persistent selection of the advantageous stimulus results in overall gain and conversely, persistent selection of the disadvantageous stimulus results in overall loss. After a certain number of trials, the rewarding contingencies associated with each stimulus are switched such that the previously advantageous stimulus is disadvantageous and vice versa (O’Doherty, et al 2001). Cognitive impulsivity is

associated with poor performance on the PRL task (Franken, van Strien, Nijs, & Muris, 2008).

The Stop and Go/No-go tasks are measures of the ability to inhibit motor and inappropriate responses (Newman et al, 1985; Logan et al, 1997). The Stop task is designed to assess inhibition of an already initiated motor response and is used in both animal and human tests of impulsivity. Subjects are instructed/trained to respond as quickly as possible when a certain stimulus (go signal) is presented, and to inhibit their responses when a tone is heard (stop signal). The tone is presented on random trials and at different delays following the go signal presentation. The delays to the stop signal are adjusted until the subject inhibits his or her responses on approximately 50% of trials. In contrast, the Go/No-go task is a learning task designed to assess subjects' ability to inhibit inappropriate responses. Subjects are asked/trained to respond only to one stimulus category (i.e., letters) and to withhold responding to another stimulus category (i.e., numbers). Thus, both the Stop task and Go/No-go tasks assess motor and self-control aspects of impulsivity.

The IGT is one of the most popular and sophisticated tasks in that it simulates a gambling game that offers immediate rewards against delayed punishments (Bechara, Damasio, Damasio and Anderson, 1994). The IGT is a card selection task with four decks of cards that vary in gains and losses. At the outset, participants are given a certain amount of hypothetical money to play the game. The goal is to maximize profit by the end of the game. At each trial, the participant is required to choose one card out of the four decks. Feedback about gains and losses is provided after each choice is made. Two decks of cards are associated with an occasional large gain but an overall expected loss while the two remaining decks are associated with a small constant gain leading to a positive gain in the long run. In short, the IGT measures the ability to choose between two or more options with different outcomes. Subjects with high impulsivity show weaknesses in learning the reward and punishment associations in order to make appropriate decisions (Franken et al, 2008).

Neural substrates of Impulsivity

Using the laboratory measures described above, researchers have been examining the neural substrates that mediate impulsivity. This work has revealed that the prefrontal cortex (PFC), including the orbitofrontal gyri and the anterior cingulated cortex (ACC), is important for executive functions such as attention, feedback monitoring and motivation, as well as the integration of sensory, affective and associative information (Carmichael & Price, 1995). The PFC has reciprocal projections with the orbital frontal cortex (OFC). Damage to the OFC produces a loss of self-regulation (Bechara et al, 1994; Rolls, 2000). That is, damage to the OFC results in a deficit of self-control, one of the aspects of impulsivity. Furthermore, the OFC is essential for assigning value to environmental stimuli, which then influences future actions (Shoenbaum et al, 1998). The striatum is reciprocally connected to the PFC and is also thought to contribute to impulsive behaviour. Lesions of the nucleus accumbens core, but not shell, region increase impulsive choice for small immediate rewards (Cardinal, Pennicott, Lakmali

Sugathapala, Robbins, & Everitt, 2001). Furthermore, lesions to both the core and shell of the nucleus accumbens increase preference for larger delayed rewards (Acheson, et al., 2006). Researchers have also gained an understanding of the neurobiology of impulsivity through the study of ADHD populations. Since the PFC projects to many subcortical regions (e.g., dorsal and ventral striatum, thalamus, amygdala, substantia nigra, and ventral tegmental), PFC dysfunction likely leads to disinhibition in these regions (Alexander, DeLong, & Strick, 1986). Both dopamine (DA) and noradrenaline (NA) are important for normal prefrontal functioning (Goldman-Rakic, Muly, & Williams, 2000). Therefore, there is converging evidence to support the idea that a dysfunction in cortico-striatal systems disrupts attention and disinhibition (Teicher, Anderson, Polcari, Glod, Maas, & Renshaw, 2000). This general hypothesis is supported by the effectiveness of pharmacological treatments for ADHD, including the stimulants methylphenidate and dextroamphetamine which are known to affect both neurotransmitter systems and are more effective than drugs with higher selectivity (Zametkin, Karoum, & Rapoport, 1987). These drugs mediate dopaminergic and noradrenergic activity in cortical and subcortical brain regions (Biederman & Faraone, Current concepts on the neurobiology of Attention-Deficit/Hyperactivity Disorder., 2002). Methylphenidate and amphetamine stimulate the release, as well as inhibit the reuptake, of catecholamines (dopamine and noradrenaline), thus enhancing activity in these neurotransmitter systems (Pliszka, McCracken, & Maas, 1996).

Recently, researchers have turned their attention to modafinil (an atypical stimulant) as an effective treatment for ADHD. Modafinil is a D2 agonist but has a very weak affinity for DA, NA and serotonin (5-HT) reuptake transporters (Madras, Miller, & Fischman, 2005; Minzenberg, Watrous, Yoon, Ursu, & Carter, 2008). In addition, modafinil has no affinity for a wide range of neurotransmitter receptors, ion channels, other reuptake transporters, and no evidence that it has an effect on second messenger systems (Minzenberg et al, 2008). Despite this apparent lack of activity, positron emission tomography (PET) experiments have shown that intravenous administration of modafinil occupies a significant proportion of DA and NA receptor sites in the monkey striatum and thalamus (Madras et al., 2006). In randomized, double-blind, placebo-controlled clinical trials, modafinil was found to produce moderate, but highly significant, reductions in ADHD symptoms in children and adolescents (Biederman, et al., 2005; Swanson, et al., 2006; Greenhill, et al., 2006). Furthermore, modifinil differs from typical stimulants like methylphenidate in that it reduces the reinforcing effects of injected or smoked cocaine, increases abstinence from cocaine in a placebo-controlled clinical trial and does not possess reinforcing effects on its own, suggesting that it has low abuse potential (Dackis, Kampman, Lynch, Pettinati, & O'Brien, 2005; Jasinski, 2000; Rush, Kelly, Hays, Baker, & Wooten, 2002). Importantly, modafinil reduces impulsivity and risky decision-making in adults with ADHD and improves ADHD symptoms overall (Turner, Robbins, Clark, Aron, Dowson, & Sahakian, 2003; Greenhill, et al., 2006). Modafinil may be particularly well suited for treating disorders of impulse control because it decreases the desire to gamble and the salience of gambling words in high impulsivity individuals, but increases these scores in low impulsive individuals (Zack & Poulos, 2009). Despite the evidence that modafinil is possibly acting on a neural substrate that differentiates between high and low impulsivity, it is not an accepted treatment for ADHD in children and adolescents due to its side-effects which include skin rashes and the potential life-threatening Stevens-Johnson Syndrome (Heal, Chetham, & Smith, 2009).

Serotonin is associated with behavioral and cognitive impulsivity, but very few studies have investigated the role of 5-HT in ADHD. Low cerebrospinal fluid levels of serotonin increase impulsive, violent or self-destructive behaviour in humans (Linnoila, Virkkunen, Scheinin, Nuutila, Rimon, & Goodwin, 1983). However, studies using a more direct measure of 5-HT levels in the PFC (in vivo microdialysis) showed that elevated levels of 5-HT may also be responsible for lack of impulsive control (Dalley, Theobald, Eagle, Passetti, & Robbins, 2002). Furthermore, 5-HT depletion attenuates the ability of amphetamine to decrease impulsive choice on a delay-discounting task in rats (Winstanley, Dalley, Theobald, & Robbins, 2003). It is likely therefore, that impulsivity is mediated by the monoamine neurotransmitter system, specifically the 5-HT system, which has an abundant receptor distribution throughout the entire cortex (King, Tenney, Rossi, Colamussi, & Burdick, 2003).

Reward Sensitivity

Reward sensitivity is a term adopted from Gray's reinforcement sensitivity theory (RST) of personality (Gray, 1987; Pickering, Diaz, & Gray, 1995). In short, RST assumes that individuals with heightened impulsivity are more sensitive to signals of reward compared to low impulsive individuals. Therefore, impulsivity is conceptualized as the primary trait reflecting reward sensitivity. Gray's interpretation of impulsivity is that it was a trait level manifestation of the Behavioural Activation System, which mediates sensitivity to rewards (1987). Recent evidence however, points to the conceptual distinction between reward sensitivity and impulsivity constructs (Corr, 2004; Franken, Muris, & Georgieva, 2006). According to RST, there are individual variations in the sensitivity of basic brain and behavioural systems that respond to punishing and rewarding stimuli. The two basic systems discussed in the RST are the Behavioural Inhibition System (BIS) and the Behavioural Approach System (BAS). According to the original RST, inhibition is activated by conditioned stimuli associated with punishment or the cessation of reward whereas approaches activated by stimuli associated with reward or cessation of punishment. The complex nature of BAS should be seen from an evolutionary perspective in relation to appetitive goals. Achieving BAS goals often requires planning activities and restraining inappropriate impulsive behaviour (Corr, 2004). Therefore, reward sensitivity and impulsivity are not the same theoretical construct.

RST assumes that individuals at the extremes of the BIS and BAS dimensions are at increased risk for developing psychopathology (Pickering & Gray, 1999). Quay (1997) hypothesized that an underactive BIS underlies the symptoms of ADHD. That is, a hypoactive BIS supposedly provides little input leading to an extinction of behavioural inhibition following a cue that signals punishment or non-reward (as manifested in impulsive ADHD behaviours). Conversely, an alternative explanation could be that ADHD symptoms (hyperactivity and impulsivity) are caused by an overactive BAS (Newman & Wallace, 1993). Here, there is a failure to inhibit responses in the presence of strong reward cues, resulting in the characteristic impulsive symptoms of ADHD. Nevertheless, in one study, BAS scores can be significant predictors of ADHD symptoms (hyperactivity and impulsivity) while BIS scores were not, suggesting that ADHD symptoms are associated with BAS hyperactivity (Mitchell & Nelson-Gray, 2006).
BAS has also been used to explain substance abuse. BAS theories of substance abuse propose that pursuing an action that might result in reward, with little attention for the potential negative consequences, is a result of activity in the BAS. For instance, individuals with substance abuse problems such as drug addicted inpatients were found to report higher levels of BAS sensitivity compared to controls (Franken, Muris, & Georgieva, 2006). Furthermore, treatments that provide an alternative source of reward (i.e., methadone) are successful in treating individuals with substance abuse problems, such as heroine and heroin-cocaine dependence (Kreek, Zhou, Butelman, & Levran, 2009).

Much like the construct of impulsivity, it is not clear whether self-report and laboratory based measures of reward sensitivity measure the same process. There are two known self-report measures of reward sensitivity: the Behavioural Inhibition/Behavioural Activation Systems scale (BIS/BAS) and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) (Carver & White, 1994; Franken & Muris, 2006). The BIS/BAS is a 20 item self-report questionnaire designed to assess BIS reactivity and three types of BAS reactivity (reward responsiveness, drive and fun-seeking). The SPSRQ consists of 48 items with a yes/no response and is divided into two subscales: sensitivity to punishment and sensitivity to reward. The BIS scale is positively correlated with the sensitivity to punishment subscale of the SPSRQ and the BAS correlates negatively with the sensitivity to punishment scale. However, there is no correlation between the BAS and the sensitivity to reward subscale of the SPSRQ (Beck, Smits, Claes, Vandereycken, & Bijttebier, 2009). At a conceptual level the scales measure different constructs and although the subscales are inter-correlated they do not provide consistent results.

Furthermore, reward sensitivity does not have a direct laboratory measure. In the context of decision-making, it is often studied indirectly in paradigms of rewarded outcomes and predictions because reward sensitivity is mediated by expectation (Schultz, 2000).

One commonly used task is the Monetary Incentive Delay task (Abler, Erk, & Walter, 2005). Here, subjects are shown the money they could earn by performing the task successfully. All subjects correctly believe that they would receive the earned money at the end of the experiment. Each trial starts with a cue indicating the amount of money they could win with a correct response. After a delay, subjects must correctly react to one of two target symbols within a fixed interval. Since the task difficulty is very low, a probabilistic reward pattern is used (reward is not paid out in 40 predefined trials out of 100). Thus, reaction times are used as measures of motivation. Feedback is provided after every trial, notifying subjects about the amount of money they had earned. A recent fMRI study has shown that subjects with high BAS scores appear to be sensitive mainly to positive outcomes in the Monetary Incentive Delay task and to a lesser extent to the omissions of rewards. Conversely, subjects with low BAS scores as well as those with high BIS scores displayed a stunted response to rewards (Simon, et al., 2009). Emotional states affect reward sensitivity. For instance, depression is seen as a deficit in the approach motivation system. In a modified version of the Monetary Incentive Delay task patients with Manic Depressive disorder showed altered sensitivity to reward and punishment (Shankman, Klein, Tenke, & Bruder, 2007). That is, patients with depression were associated with deficits in BAS.

The IGT is also commonly used in studies of reward sensitivity. One of the dependent measures in the IGT is impulsive perseveration, or the continuing selection of a rewarding option that is associated with high punishment. In the context of gambling or drug addiction, this can be conceptualized as oversensitivity to reward and/or an inability to inhibit reward-seeking behaviour.

Reward sensitivity may also be studied in the lab using reversal learning paradigms or conditioned preference tasks. In the first, subjects (humans or animals) learn that one cue is associated with a positive reinforcer such as food. After the association is acquired, the meaning of this cue is reversed such that the previously correct response must be inhibited. Recently, it was found that PG is related to response perseveration on a probabilistic reversal learning task and also had diminished reward and punishment sensitivity (de Ruiter, Veltman, Goudriaan, Oosterlaan, Sjoerds, & van den Brink, 2009). Conditioned preference tasks are used extensively in animal studies and have recently been adopted for human populations (Johnsrude, Owen, Zhao, & White, 1999). This Conditioned Pattern Preference (CPP) task measures the preference for abstract visual cues as an index of implicit emotional learning. This task also has measures of explicit and implicit memory. Here, explicit memory is operationalized as the subjects' knowledge of experimental conditions or the reward contingency. Conversely, implicit memory is measured as the correct identification of rewarded contingencies, with no awareness of these contingencies during conditioning.

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Neural Substrates of Reward Sensitivity

The neurobiology of the BAS is primarily located in the basal ganglia, with a central role played by mesolimbic DA projections from the ventral tegmental area (VTA) to the ventral striatum (a key component of which is the nucleus accumbens), and also mesocortical DA projections to prefrontal cortex (Depue & Collins, 1999; Knutson &

Cooper, 2005; McClure, York, & Montague, 2004; Pickering & Gray, 1999). Dopamine is critical in reward processing and prediction (Fiorillo, Tobler, & Schultz, 2003; van Ooyen & Roelfsema, 2006). Phasic activity of DA neurons increases in response to unpredicted reward, decreases in response to unpredicted non-reward, and is sustained when rewards are fully predicted (Day, Roitman, Wightman, & Carelli, 2007; Pickering & Smillie, 2008). This suggests that DA communicates reward prediction error, and that BAS activation is triggered by unpredicted reward and sustained by predicted reward. Studies involving non-human primates have shown that DA neurons in the VTA respond to unexpected primary rewards and eventually to stimuli that predict them (Mirenowicz & Schultz, 1994). Furthermore, changes in DA firing parallel changes in reward outcome and this is also shown in behaviour. There are projections to and from the PFC (i.e., goal directed behaviour) and ventral striatum (i.e., appetitive behaviours) (Schultz, 2006; Haber, 2003). These areas have many DA neurons and these connections may form a functional neuroatomical circuit that supports behaviour resulting in the most favourable outcomes.

Human imaging studies have implicated the nucleus accumbens and OFC in the representation and predictions of error. For instance, unpredictable reward deliveries have been shown to increase activity in the nucleus accumbens core and ventral striatum, as opposed to predictable delivery (Berns, McClure, Pagnoni, & Montague, 2001; O'Doherty, Dayan, Friston, Critchley, & Dolan, 2003; O'Doherty J. , Dayan, Schultz, Deichmann, Friston, & Dolan, 2004). Nevertheless, the role of the OFC in reward sensitivity is not clear. In the context of prediction error, some studies have shown OFC activation and others have not (Berns, et al, 2001; O'Doherty et al., 2003; O'Doherty J. , et al., 2004; McClure, Berns, & Montague, 2003). Kringelbach and Rolls (2004) suggest that a medial-lateral distinction and an anterior-posterior distinction monitor reward and value evaluation of punishers, respectively. Furthermore, in monkeys it has been shown that both the nucleus accumbens core and OFC had greater activation to non-rewarded trials but the accumbens appeared to be most sensitive to violations in expected rewarded outcomes, which suggests distinct roles for fronto-striatal circuitry in reward prediction and in responding to violations in expectations (Spicer, Galvan, Hare, Voss, Glover, & Casey, 2007).

Serotonin has also been implicated in reward sensitivity for patients diagnosed with manic depressive disorder (MDD). MDD patients carrying the ‘ss’ variant of the serotonin transporter promoter polymorphism showed less persistence and tended to be influenced by high immediate reward (Must, Juhasz, Rimanoczy, Szabo, Kéri, & Janka, 2007). Therefore the serotonin neurotransmitter might be involved in reward sensitivity, although the specific neural substrates involved are not yet known. Conditioned emotional reward, as measured in the CPP task, also involves activation of the ventral striatum and amygdala areas implicated in the process by which conditioned stimuli acquire incentive value (Cox, Andrade, & Johnsrude, 2005; Holland & Gallagher, 1999; Pears, Parkinson, Hopewell, Everitt, & Roberts, 2003). Moreover, ventral-striatal activation occurs in anticipation of reward whereas OFC activation is associated with reward outcomes (O'Doherty, et al, 2001).

Impulsivity and Reward Sensitivity

The co-occurrence of altered impulsivity and reward sensitivity across disorders could indicate that a similar deficit explains alterations in these two processes. In line with this idea, some authors conceptualize impulsivity as oversensitivity to signals of reward, relative to signals of punishment (Potts, George, Martin, & Barratt, 2006). More specifically, impulsivity would be manifested when a reward-seeking drive persists (or fails to be inhibited), despite the potential for even greater punishment. The idea that impulsivity and reward sensitivity are connected fits with evidence that individuals with high impulsive traits are unusually sensitive to reward salience (Potts et al, 2006), as well as being less sensitive to punishment and more sensitive to reward (O'Doherty, et al, 2001). A possible connection between impulsivity and altered reward sensitivity is strengthened by evidence that both are associated with alterations in orbitofrontal cortex (OFC) function. As noted above, patients with OFC damage show disinhibited or socially inappropriate behaviour as well as emotional changes. In addition, in psychiatric patients with affective disorder, OFC volume is correlated with laboratory measures of impulsivity (Antonucci, Gansler, Tan, Bhadelia, Patz, & Fulwiler, 2006).

Proposed Study

Given the apparent association between impulsivity and altered reward sensitivity, this study examined whether individuals who exhibit high and low trait impulsivity performed differently on tests of conditioned reward. Impulsivity was assessed using two self-report questionnaires: the EIQ and BIS-11. Reward sensitivity was assessed in a Probabilistic Reversal Learning task (PRL) and the CPP. In line with previous studies (Franken, van Strien, Nijs, & Muris, 2008), high impulsive individuals were expected to display a reversal learning deficit, marked by a persistent choice of the previously reinforced stimulus. In addition, high impulsive individuals were more likely to be sensitive to reward-paired stimuli in the CPP task, compared to low impulsive participants. This was expected to be shown in stronger preference formations for high impulsives on the patterns associated with the reward.

Both impulsivity and reward sensitivity were assessed in an Emotional Stroop task. This test is often used to assess the emotional processing in pathological populations (e.g., depression, drug addiction) by testing implicit cognitive biases in response to emotionally salient words (Dresler, Mériau, Heekeren, & van der Meer, 2009). Impulsivity is associated with disruptions in attention, planning, organization and dysregulated emotional responses. Therefore high impulsive individuals were expected to display an attentional bias for salient, emotional stimuli. This would result in longer colour-naming latencies for negative or positive valent words (e.g., "plague", "virus" or "desire", "party") compared to the neutral words (e.g., "clock", "window"). Taken together, these three tasks were meant to tap into different aspects of reward salience in high impulsive individuals, and differences in performance (sensitivity versus persistence) were expected to be reflected in response patterns.

Chapter 2

Method and Procedure

Participants

Participants were 186 healthy undergraduate and graduate students (128 females and 58 males) from Queen's University, recruited through classes and a student volunteer subject pool. Eligibility criteria for the study included that the participant was a fluent speaker of English and had normal or corrected-to-normal vision. Each participant completed the Barratt Impulsiveness and Eysenck Impulsivity scales prior to performing the CPP, Emotional Stroop and PRL tasks.

Measures

The Barratt Impulsiveness Scale

The Barratt Impulsiveness Scale, version 11, (BIS-11) is a 30 item self-report questionnaire examining impulsive traits (Appendix A; Patton, Stanford & Barratt, 1995). The participant rates the statements on a 4-point scale: rarely/never, occasionally, often or almost always. All the items on the scale are correlated, with a Pearson coefficient ranging from $r = 0.15$ to $r = 0.42$. The BIS-11 also contains 4 subscales: attention, motor impulsiveness, self-control and cognitive complexity. The BIS-11 has been translated into different languages and its test-retest reliability ranges from 0.71 to 0.89 (Someya, Sakado, Seki, Kojima, Reist, Tang, & Takahashi, 2001; Fossati, Di Ceglie, Acquarini, & Barratt, 2001).

The Eysenck Impulsivity Scale

The Eysenck Impulsivity Scale (EIQ) is a 54-item self-report questionnaire in which respondents answer the items on a dichotomous (i.e., 'yes' and 'no') response scale, Appendix B. The 19 item impulsivity subscale consistently identifies a specific form of impulsivity that correlates with problem gambling (Blaszczynski et al., 1997; Clarke, 2004). Participants' ratings on the EIQ were summed according to those methods recommended by Eysenck (1985). The EIQ is a frequently employed questionnaire to assess the personality trait of impulsivity (see Lijffijt et al., 2005). The scale has good psychometric properties, with good reliability and validity (Eysenck et al., 1985; Dickman, 1990).

Behavioural Tasks

The behavioural component of the experiment was comprised of three tasks: the CPP task, an Emotional Stroop task and a PRL task (O'Doherty et al. 2001). The CPP task lasts approximately 40 min whereas the Stroop and PRL tasks each take approximately 15 min to complete. The CPP was administered first due to its length. The Stroop and PRL tasks were administered in a counterbalanced manner to account for any effects of fatigue. Participants were told that they were allowed to take a break in between tasks if they chose to. Less than 5 participants took a break between tasks and those that did paused for an average of 2-3 min (usually to check their phone or drink some water).

The Conditioned Pattern Preference task

The CPP task is a computerized implicit learning task developed by Johnsrude and colleagues (1999). For this task, participants chose a food reward (either Mars Company M&M's® chocolate coated candy or General Mills' Cheerios Snack Mix) before beginning the task, which they were allowed to eat following each correct task trial.

The CPP consisted of 3 different phases that were presented in a fixed order: *Formation*, *Judgment* and *Questions*. Before starting the *Formation* phase, participants were given the following instructions: "*You will be presented with 3 boxes. By using the keyboard in front of you, you can select a box to reveal either a black or red ball. There are 2 black balls and 1 red ball hidden in each trial. Your task is to find as many red balls as possible. Each time you find a red ball, you will eat an M&M® or piece of Cheerios Mix. While you are trying to find the red ball, we would like you to pay attention to how many black balls you come across. You will be asked throughout the experiment to report how many black balls you uncover*."

Therefore participants were asked to keep track of incorrect responses by counting the number of times a black ball appeared at each location. This counting task provided a measure of working memory. The counting task consisted of participants' estimation of black balls they saw in each of the three boxes. This assessment of working memory was calculated by subtracting the sum of the number of black balls viewed at each trial block, from each participant's estimate. Participants completed a total of 180 trials over 6 blocks. Unbeknownst to the participants, the trial order was pseudorandom and fixed, as shown in Figure 1.

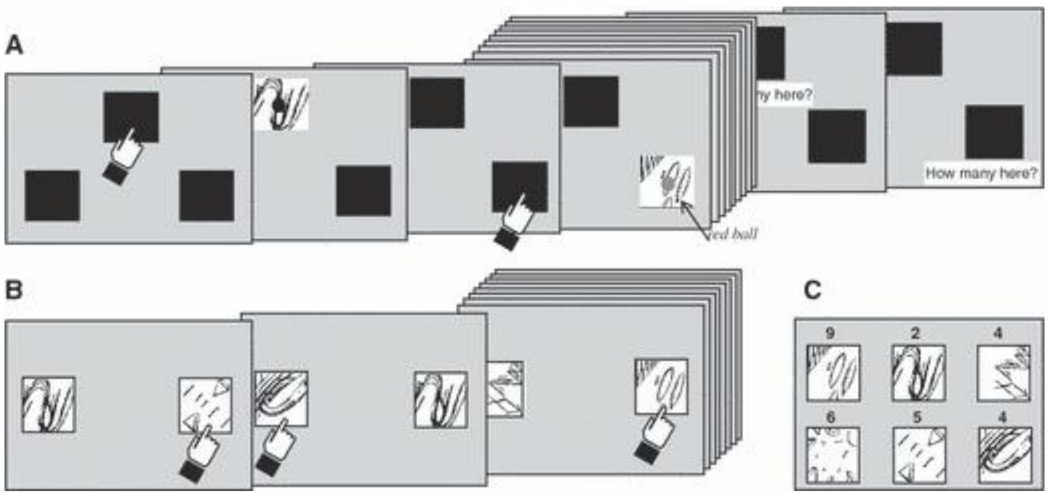

Figure 1 The three stages of the Conditioned Pattern Preference task

In the *Formation* stage (A), participants are instructed to find the red ball behind 1 of the black boxes. When participants find a red ball, they hear a melodic flourish and are allowed 1 food reward. After a certain number of trials, participants are asked "How many here?" asking a participant to report how many black balls they noticed at these locations. Therefore, participants must find the red ball, while simultaneously keeping track of how many black balls they have noticed. In the *Judgment* phase (B), participants are shown 2 patterns and are asked to pick the 1 that they prefer. In the final *Questions* phase (C), participants are presented with the total tally of their choices from the *Judgment* phase and are questioned why they preferred certain patterns over others.

There were 3 abstract monochrome stimulus patterns viewed by participants and these were paired with the red ball in a 90%, 50%, and 10% reward contingency such that the pattern-reward pairing was not obvious to the participant. During the *Judgment* phase of the task, participants were shown 6 patterns: 3 familiar patterns previously viewed in the *Formation* phase and 3 novel patterns. The purpose of the *Judgment* phase was to assess whether participants developed a preference for the conditioned patterns from the *Formation* phase by tallying the number of times each of the patterns was chosen. In the

Questions phase, the participants were asked which patterns they preferred. The purpose of the *Questions* phase was to assess the participant's knowledge of the experimental manipulation. That is, it specifically probes whether participants attributed their pattern preference to physical attributes of the pattern, or whether they overtly recognized the patterns from the conditioning procedure in the *Formation* phase of the task. Participants were asked: ''You picked this pattern X times. Why did you prefer this pattern?'' for their top 2 choices. They were also asked: ''You only picked this pattern X times. Why didn't you like this pattern for the 2-least-chosen patterns''. Up to this point in the task, there has been no explicit mention of the relationship between the patterns and the red and black ball pairings from the Formation phase. With the Questions phase screen still present on the computer, participants were explicitly questioned concerning their knowledge of the pattern contingencies. Participants were asked whether they noticed any of the patterns during the first phase of the task, and if so, which ones. Participants were also asked whether they noticed that any pattern was paired frequently with the red ball and to point out which one. They were also asked which pattern most appeared with the black ball. Answers to all these questions were dichotomously scored as correct/ incorrect. Participants that explicitly mentioned the relationship between the patterns and the red and black ball pairings were categorized as having 'Task Knowledge'. Likewise, subjects that correctly identified the patterns associated with the red or black ball pairings were categorized as having '90%' or '10%' Recognition'.

There were three versions of the task. In each version, a different set of pattern-reinforcement contingency pairings was used. Thus, in one version, Pattern A was accompanied by the reward (red circle, melodic flourish, food) on 90% of trials in which it appeared (i.e.: 54 trials) and by negative feedback (black circle, buzzer sound and no food) on 10% of those trials (i.e.: 6 trials). Pattern B was accompanied by reward on 50% of trials in which it appeared and by negative feedback on the other 50%. Pattern C was accompanied by reward on 10% of trials and by negative feedback on the other 90%. In the second version of the task the ratios were Pattern A, 10: 90; Pattern B, 90:10; Pattern C, 50:50, while in the third version, the corresponding ratios were: 50: 50; 10: 90, and 90:10. Table 1 shows the frequencies of subjects assigned to each version of the task.

Table 1 Participants assigned to versions A, B and C of the Conditioned Pattern Preference task.

		CPP version			
		A	B	C	Total
Sex	Female	44	41	41	126
	Male	21	20	15	56
Total		65	61	56	182

The trial order was also pseudorandom and fixed. The rarest combinations were always presented just before or just after the more frequent combinations (e.g., for the first version described above, Pattern A paired with a black circle was presented just after Pattern A paired with a red circle). In addition, an identical pattern/reinforcement pair could not occur more than twice in a row. These provisions served to break up runs of similar trials which might otherwise have alerted the subjects to the different reinforcement contingencies. In addition, each block of trials contained an equal number of red and black circles and at least one occurrence of each of the six possible combinations of circles and patterns.

The Emotional Stroop task

The Emotional Stroop task was a modified version of the classic Stroop task, in which words were presented in different colours and participants were asked to name the colour of the stimuli. The Emotional Stroop was used to assess attention to valent stimuli. Words were twenty pleasant (e.g., love), unpleasant (e.g., virus) and twenty matched neutral (e.g., clock) words, as used by Dresler et al., (2007). The word list is included in Appendix C. The software used to design the Stroop task was Direct RT by Empirisoft©. It has a timing resolution of 1 millisecond (msec). Furthermore, response timing is synchronized with the screen display so timing always begins when the screen first begins to draw (eliminates 10-17 msecs of random error). The keyboard was used to collect responses on keys. Appropriately coloured stickers were placed on the keyboard representing the correct colour response. Keyboards generally have a specificity estimate of 25 msec.

Participants were instructed to indicate word colours as quickly and as accurately as possible by pressing indicated keys on a computer keyboard. Each word was presented once in four colours (red, yellow, green and blue) for a total of 240 trials. The order of test trials was random and constant across participants. Test trials were preceded by a 15-trial practice block. Each trial started with a white fixation cross appearing in the center on a grey background for 500 msec. After another 500 msec with a blank screen, a word appeared in one of the four colours, in 24 pt Times New Roman font. The word remained on the screen until the participant pressed a colour key or to a maximum of 3000 msec. Finally, a 100 mecs inter-trial pause terminated the trial with a blank screen.

The Probabilistic Reversal Learning task

Reversal learning involves the adaptation of behaviour according to changes in stimulus-outcome contingencies. This ability was tested in a visual discrimination task, in which subjects learn to choose a rewarded stimulus in an initial Acquisition stage, and subsequently learn to reverse their choice to the previously non-rewarded stimulus in a Reversal stage (Swainson et al., 2000). This task was administered using a button box. On each trial, subjects were presented with two visual patterns (rectangles of coloured stripes), as shown in Figure 2. These patterns appeared in two randomly chosen boxes out of four possible boxes. The task consisted of two stages, starting with a simple probabilistic visual discrimination, in which subjects made a two-alternative forced choice between two colours. Participants received the following instructions:
"On each go, the same two patterns will be presented. One of the patterns is correct and the other pattern is incorrect and you have to choose the correct pattern on each go. However, on some goes, the computer will tell you that you were wrong even if you chose the correct pattern. Your task is to stick to the pattern that is usually correct. So in other

words always choose the pattern that is correct more often than the other pattern. At some point during the task, the rule may change so that the other pattern is now usually correct. You then have to follow the new rule and choose the new pattern. It is important that you only start choosing the other pattern when you were sure that the rule has changed". The 'correct' stimulus (always the first stimulus touched) received an 80:20 ratio of positive:negative feedback and the opposite ratio of reinforcement was applied to the 'incorrect' stimulus. After having completed 40 trials of the initial discrimination, the task proceeded to the second, reversal stage (also 40 trials) in which the reward contingencies were reversed.

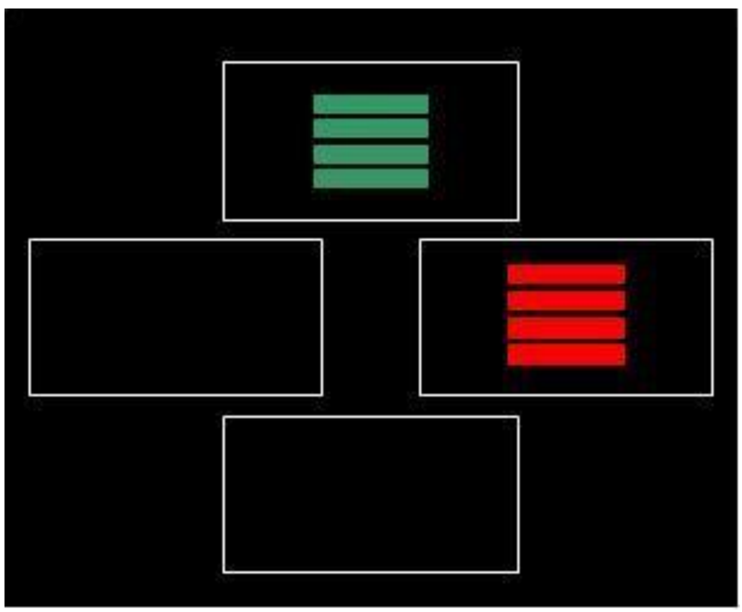

Figure 2 Screen display of the probabilistic reversal learning task

Proposed Analyses

Preference formation data in the CPP task were analyzed using a 4-Factor (Sex, Impulsivity, Test Version) repeated-measures ANOVA, with Pattern as the within-subjects factor. Next, preference formation scores were analyzed on those subjects that attributed their pattern preference to the physical attributes of the pattern (Task Knowledge group) and those that overtly recognized the patterns from the conditioning procedure (Recognition groups). Performance on the counting (distractor) task was assessed using a repeated-measures ANOVA with Trial Block as the within-subjects factor and Sex and Impulsivity as the between-subjects factor.

For the Emotional Stroop task, a 2 (Sex) X 3 (Impulsivity) X 3 (Word Category) repeated-measures ANOVA was used to analyze Number of Errors as well as RT (msec).

For the PRL, Acquisition and Reversal stages were analyzed separately. Therefore, two different chi-square tests were used to examine the proportions of low, medium and high impulsive subjects that reached criterion for that stage. Finally, a multivariate ANOVA for each Stage was used, with Sex and Impulsivity as between-subjects factors and Errors to Criterion and Total Errors per Stage as the dependent measures.

Chapter 3

Results

Participant Demographics

Of the 186 participants, 182 (126 females and 56 males) completed the study; three were interrupted by cell phone calls and had to leave the experiment and one participant did not meet the requirements of English language fluency (i.e., they did not understand the instructions well enough to partake in the study). The mean age of the remaining participants was 20.05 (*SE* = .21) years of age. Female participants ranged in age from 18 to 26 years of age, with a mean age of 20.03 (SE = .26) and male participants ranged in age from 18 to 27 years of age, with a mean age of 20.10 (SE = .32).

Measures

The Barratt Impulsiveness Scale

The mean total BIS-11 score for the 182 participants was 64.39 (*SE* = .79), with scores ranging from 37 to 105. Furthermore, the means for the four subscales were: attention *M* = 11.45 (*SE* = .14), motor impulsiveness *M* = 15.27 (*SE* = .24), self-control *M* = 16.47 (*SE* = .20) and cognitive complexity *M* = 12.85 (*SE* = .16). There was no significant difference between female and male participants in the total BIS score or on the four subscales, as shown in Table 2.

Table 2 Mean (SEM) total scores on the Barratt Impulsiveness scale (BIS-11) with its four subscales (i.e., attention, motor, self-control and cognitive), and the Eysenck Impulsivity (EIQ) scale for female (n = 128) and male (n = 58) participants.

		Female	Male	Total
BIS-11				
	Attention	11.47 (0.16)	11.37 (0.27)	11.44 (0.14)
	Motor	15.39 (0.29)	15.02 (0.40)	15.27 (0.24)
	Self-Control	16.44 (0.24)	16.84 (0.39)	16.56 (0.20)
	Cognitive	12.71 (0.19)	13.41 (0.32)	12.92 (0.16)
	Total	65.27 (0.97)	62.43 (1.32)	64.39 (0.79)
EIQ		7.00 (0.33)	7.00 (2.99)	6.97 (1.71)

The scores on the four subscales of the BIS-11 were used to separate participants into low, medium and high impulsive groups using an inter-quartile split, as shown in Table 3.

Table 3 Low, medium and high impulsive groups for the attention, motor, self-control and cognitive subscales of the Barratt Impulsiveness Scale

	Low	Medium	High
Attention	≤ 10 (n = 56)	11 & 12 (n = 82)	13 ≤ 17 (n = 49)
Motor	≤ 13 (n = 57)	14 ≤ 16 (n = 73)	17≤ 26 (n = 57)
Self-Control	≤ 14 (n = 42)	15 ≤ 18 (n = 101)	19 ≤ 24 (n = 44)
Cognitive	≤ 11 (n = 47)	12 ≤ 14 (n = 96)	15 ≤ 18 (n = 44)

The Eysenck Impulsivity Scale

The mean EIQ score for the 182 participants was 7.00 (*SE* = .33), with scores ranging from 0 to 19. There was no significant difference in mean scores on the EIQ between female and male participants, as shown in Table 1.

Composite Impulsivity Score

The BIS-11 and EIQ significantly correlated (Pearson r coefficient = .76), as shown in Figure 3. In order to increase statistical power in subsequent analyses, scores

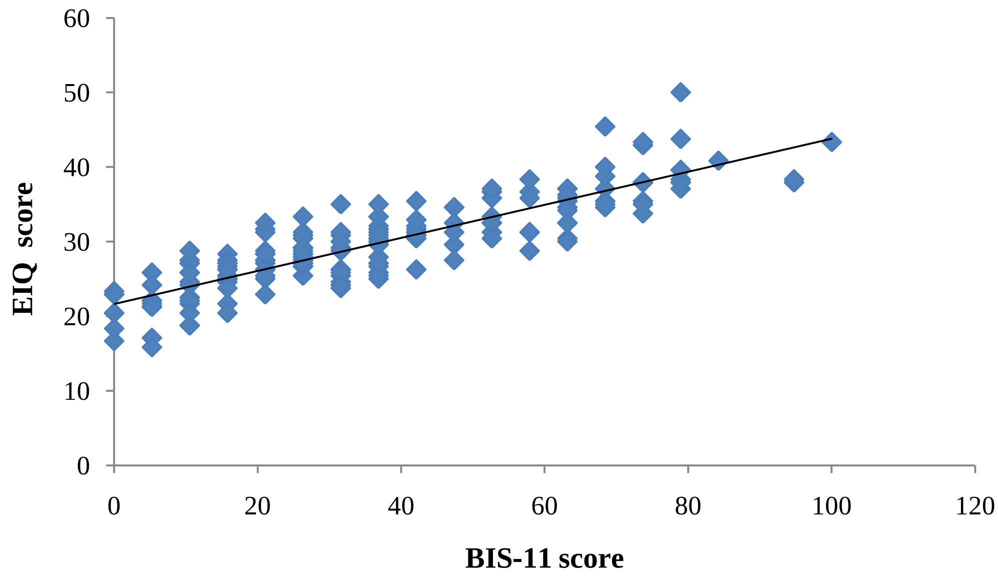

Figure 3Correlation between total scores on the Barratt Impulsiveness Scale (BIS-11) and scores on the Eysenck Impulsivity scale (EIQ).

on the BIS-11 and EIQ were standardized and then aggregated to make a composite Impulsivity score. An inter-quartile split was then used to separate participants into low (n = 46), medium (n = 91) and high (n = 45) impulsive groups. The low and high groups consisted of the first and fourth quartile, the medium group was comprised of the second and third quartiles. A one-way ANOVA revealed no significant difference between females and males ($F(1, 181) = .57$, $p = .45$) on this Impulsivity score.

Behavioural Tasks

The Conditioned Pattern Preference task

Preference Conditioning

A one-sample t-test examining mean preference scores for the 6 patterns (maximum value = 10) using a test value of 5 (the expected mean preference if participants are indifferent to a particular pattern) revealed that one of the patterns was selected significantly more frequently ($p < .01$), while 2 other patterns were selected significantly less frequently ($p < .01$), than expected.

The most preferred pattern and one of the less preferred patterns had been used in the conditioning task, while the other less preferred pattern was only viewed during the *Judgment* Phase. The pattern preference scores for the six patterns are shown in Table 4.

Table 4 Preference Score Means (SEM) from the 6 patterns used in the Conditioned Pattern Preference task

	Pattern (Formation phase)			Pattern (Judgement phase)		
Pattern label	X*	Y**	Z	P	Q	R**
Mean	7.90	4.34	5.04	4.57	4.49	3.97
Standard Error	0.18	0.22	0.20	0.23	0.23	0.22

* = pattern selected significantly more frequently
** = pattern selected significantly less frequently

CPP data from 4 participants (3 females, 1 male) were excluded due to incomplete or missing values. Table 5 shows the frequencies of low, medium and high participants that were assigned to each version of the CPP task.

Table 5 Participants in low, medium and high impulsive groups assigned to each version of the Conditioned Pattern Preference task.

		CPP version			Total
		A	B	C	
Impulsivity	1	12	17	17	45
	2	38	27	25	89
	3	15	17	14	44
Total		63	60	55	178

Data from the remaining 178 participants were analyzed using a 4 factor (Sex, Impulsivity and Test Version) repeated-measures ANOVA, with patterns that were paired with the reward on 90% and 10% of conditioning trials as the within-subjects factors (i.e., Pattern), shown in Table 6.

Table 6 Results from 4-Factor repeated-measures ANOVA for the Conditioned Pattern Preference task

Multivariate Tests					
Effect	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pattern	4.82	1	156	.030	.030
Pattern X Sex	4.20	1	156	.042	.026
Pattern X Impulsivity	2.09	2	156	.128	.026
Pattern X Test Version	19.41	2	156	.000	.199
Pattern X Sex X Impulsivity	1.48	2	156	.232	.019
Pattern X Sex X Test Version	1.23	2	156	.295	.016

Pattern X Impulsivity X Test Version	0.13	4	156	.970	.003
Pattern X Sex X Impulsivity X Test Version	2.34	4	156	.057	.057

Tests of Between-Subjects Effects

Source	df	F	Sig.	Partial Eta Squared
Sex	1	.091	.763	.001
Impulsivity	2	.035	.965	.000
Test Version	2	12.96	.000	.143
Sex X Impulsivity	2	.382	.683	.005
Sex X Test Version	2	2.110	.125	.026
Impulsivity X Test Version	4	1.788	.134	.044
Sex X Impulsivity X Test Version	4	.546	.702	.014
Error	156			

The intrinsic pattern preference may explain the significant effect of Test Version as shown in Table 7. A pairwise comparison revealed that, for the 90% rewarded pattern, version A had a significantly higher mean preference score than either versions B or C ($p < .01$), and that these latter versions did not differ from one another. For the 10%

rewarded pattern, version B had a significantly higher mean preference score than versions A and C ($p < .01$), while the two latter versions were not significantly different from each other ($p = .90$). Given the intrinsic preference for certain patterns, Test Version was included as an independent variable for each of the subsequent analyses in order to conservatively control for this inherent preference. Nevertheless, there was a significant effect of Pattern ($F(1, 156) = 4.82$, $p = .03$) on judgement scores in that the mean judgment score for the 90% rewarded pattern was higher ($M = 6.28$, $SE = .22$) than for the 10% rewarded pattern ($M = 5.45$, $SE = .25$).

Table 7 Means (SEM) of the Patterns used in Versions A, B and C in the Conditioned Pattern Preference task with the rewarded contingency on 90, 50 and 10 percent of the conditioning trials.

	90% Pattern	50% Pattern	10% Pattern
CPP version			
A X (90%), Y (50%), Z (10%)	8.28 (0.24)	3.93 (0.32)	5.24 (0.34)
B Y (90%), Z (50%), X (10%)	4.97 (0.37)	4.85 (0.33)	7.35 (0.37)
C Z (90%), X (50%), Y (10%)	5.17 (0.37)	8.31 (0.28)	4.08 (0.43)

CPP and Gender Effects

Although, there was a significant Pattern X Sex interaction ($F(1,156) = 4.19$, $p < .05$), there was no significant effect of sex for the pattern paired with the reward on 90% ($F(1,173) = 1.05$, $p = .31$) and 10% ($F(1,173) = 2.90$, $p = .09$) of the conditioning trials, as shown in Figure 4 A.

Of the 178 participants, 22 (13 females and 9 males) individuals explicitly related their preferences in the Questions phase to the initial pairing of the pattern with the red or black ball during the *Formation* phase. More specifically, when questioned why they liked/disliked a specific pattern, this Task Knowledge group made comments related to the conditioning such as 'the pattern was always behind the black ball'.

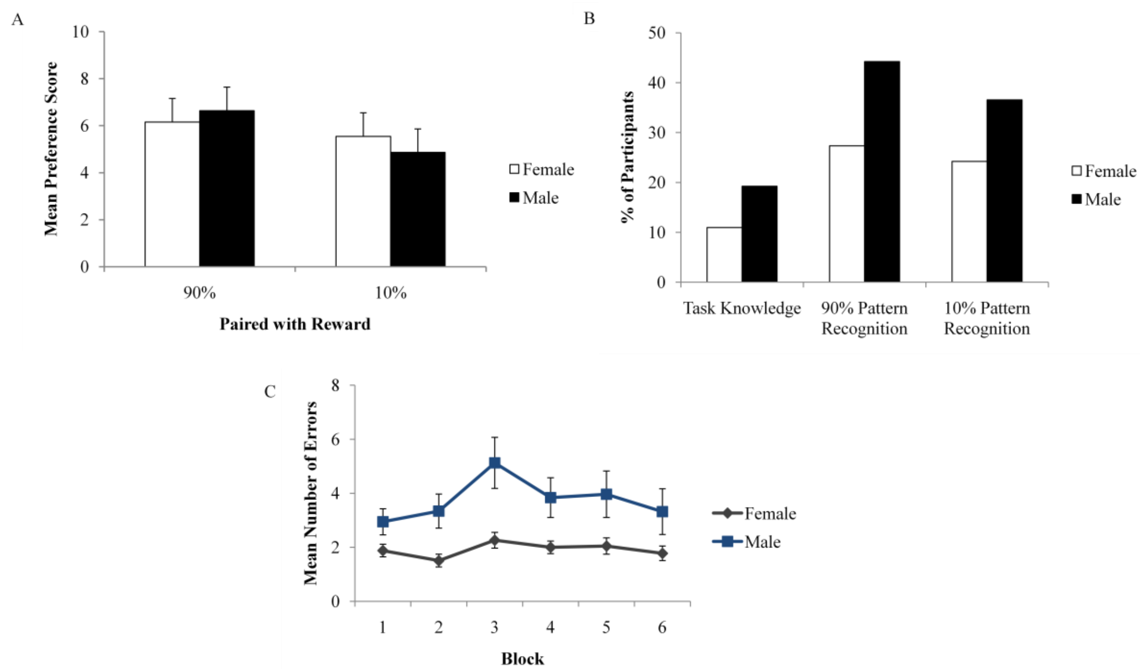

Figure 4 Performance on the Conditioned Pattern Preference (CPP) task for female and male participants.

A) Preference scores for the pattern paired with the reward on 90% and 10% of the conditioning trials. B) Percentage of participants that were aware of the conditions of the experiment (i.e., Task Knowledge), that identified the pattern paired with the reward on 90% (i.e., 90% Pattern Recognition) and 10% (i.e., 10% Pattern Recognition) of the conditioning trials. C) Mean number of cognitive estimation errors across the six blocks of trials during conditioning.

All other participants (n = 156) related their preferences to the physical characteristics of the pattern (e.g., 'I like the swirls'). Furthermore, 57 participants (35 females and 22 males) recognized the pattern associated with the reward on 90% of the conditioning trials (i.e., 90% Pattern Recognition group) and 46 participants (28 females and 18 males) recognized the pattern associated with the reward on 10% of the conditioning trials (i.e., 10% Pattern Recognition group). Some subjects had knowledge of the experimental conditions as well as recognition of the rewarded patterns. These frequencies are shown in Table 8.

Table 8 Frequency table of the number of subjects in the explicit and implicit knowledge groups

			90% Recognition Group		
			NO	YES	Total
No Task Knowledge	10% Recognition Group	NO	97	22	119
		Yes	18	19	37
		Total	115	41	156

			90% Recognition Group		
			NO	YES	Total
Task Knowledge	10% Recognition Group	NO	5	8	13
		Yes	1	8	9
		Total	6	16	22

Explicit Memory Effects and Preference Conditioning

Figure 4B shows no difference in the proportion of female and male participants in the Task Knowledge ($\chi^2(1, N = 175) = 1.88, p = .13$), 90% Pattern Recognition ($\chi^2(1, N = 175) = 2.34, p = .09$) and 10% Pattern Recognition ($\chi^2(1, N = 175) = 2.31, p = .09$) groups.

Performance on the counting task was assessed using a repeated-measures ANOVA with Trial Block as the within-subjects factor and Sex and Impulsivity as the between-subjects factors. The absolute value of errors was summed for each subject and used as the dependent measure.

As shown in Figure 4C, there was a significant gender difference in cognitive estimation errors across the six blocks of trials (F (1, 177) = 11.87, $p < .01$), in that the male subjects had an overall higher absolute number of errors (M = 3.76, SE = .44) than did female subjects (M = 1.91, SE = .30).

Explicit Knowledge and CPP performance

A 2 (Pattern) X 3 (Impulsivity) repeated-measures ANOVA was used to examine preference formation on the CPP task for participants in the Task Knowledge (n = 22), 90% Pattern Recognition (n = 57) and 10% Pattern Recognition (n = 46) groups. Next, the data were split on each of the three categories (Task Knowledge, 90% and 10% Recognition) so that the subjects that had implicit and explicit knowledge could be analyzed separately from those that did not.

Results for the preference formation analyses in the Task Knowledge group are summarized in Appendix D. In brief, there was a significant interaction of Pattern X Task Knowledge, as shown in Figure 5 A. There was also a significant effect of Pattern in the Task Knowledge group, but not in the No Task Knowledge group.

Results for the preference formation analyses in the 90% Recognition group are summarized in Appendix E. In brief, there was a significant interaction of Pattern X 90% Recognition, as shown in Figure 5 B. There was also a significant effect of Pattern in the Task Knowledge group, but not in the No Task Knowledge group.

Results for the preference formation analyses in the 10% Recognition group are summarized in Appendix F. In brief, there was a significant interaction of Pattern X 10% Recognition, as shown in Figure 5C. There was also a main effect of Pattern for the participants in the 10% Recognition group but not for participants in the No 10% Recognition group.

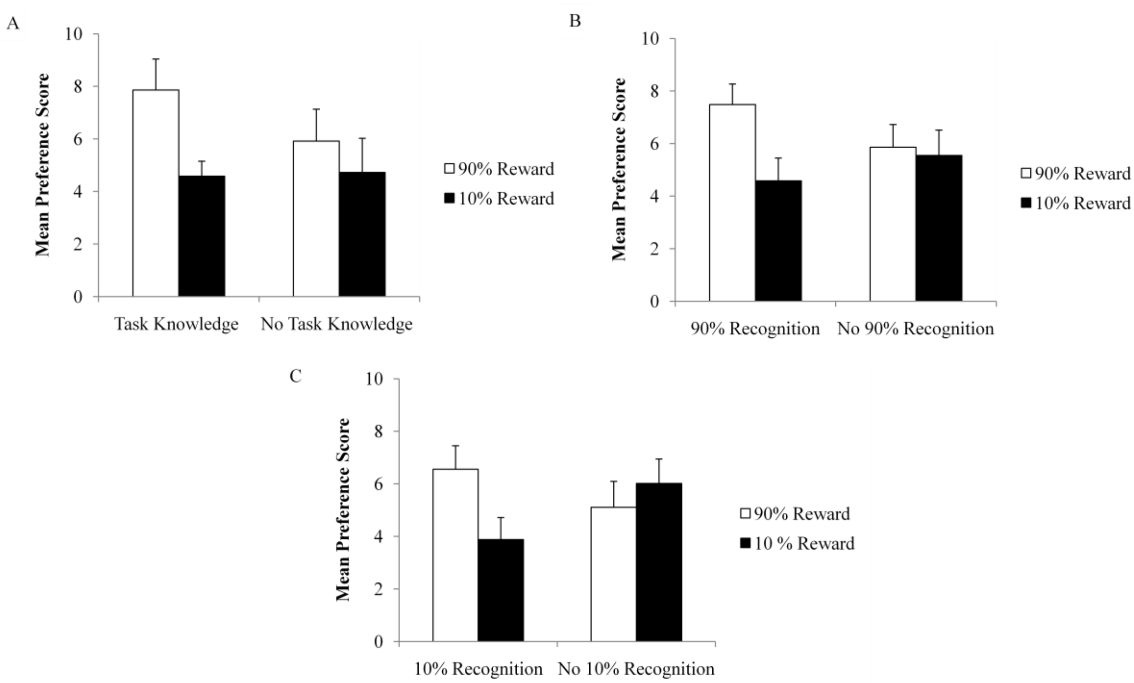

Figure 5 Performance on Conditioned Pattern Preference (CPP) task and knowledge of the experimental conditions

A) Preference scores for the pattern paired with the reward on 90% and 10% of the conditioning trials for participants that were aware of the conditions of the experiment (i.e., Task Knowledge, n = 22) and those that were not aware of the conditions (i.e., No Task Knowledge, n = 96). B) Preference scores for the participants that identified (i.e., 90% Pattern Recognition, n = 53) and did not identify (i.e., No 90% Pattern Recognition, n = 126) the pattern that was paired with the reward on 90% of the conditioning trials. C) Preference scores for the participants that identified (i.e., 10% Pattern Recognition, n = 48) and did not (i.e., No 10% Pattern Recognition, n = 132) identify the pattern that was paired with the reward on 10% of the conditioning trials.

Impulsivity and Preference Conditioning

As shown in Figure 6 A, the Pattern X Impulsivity (F (2, 156) = 2.09, p = .13) interaction was not significant and there was no overall main effect of Impulsivity on preference conditioning (F(2, 171) = .37, p = .69).

As shown in Table 4, for the pattern paired with the reward on 90% of the conditioning trials, there was no effect of impulsivity on preference formation. Although there was no significant Pattern X Impulsivity interaction, it is interesting to note that post-hoc analyses revealed that the medium impulsive group had a significantly lower preference score than the high impulsive group for the pattern paired with the reward on 10% of the conditioning trials ($p < .05$).

Impulsivity and Explicit Memory Effects

A three-way chi-square test indicated that there were no differences in the proportion of low, medium and high impulsive participants in the Task Knowledge (χ^2 (2, N = 175) = .14, p = .93), 90% Pattern Recognition (χ^2 (2, N = 182) = 5.52, p = .06) and 10% Pattern Recognition (χ^2 (2, N = 182) = 4.39, p = .11) groups, as shown in Figure 6 B.

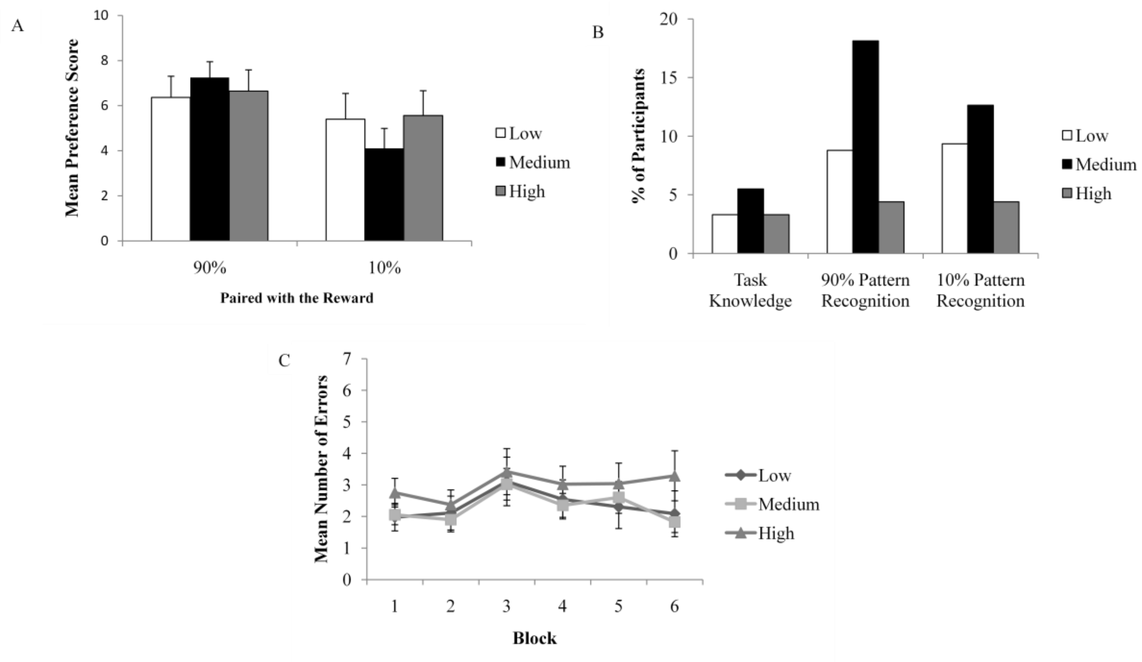

Figure 6 Relationship between Impulsivity (defined by the BIS-11/EIQ composite score) and Performance on the Conditioned Pattern Preference task

A) Preference scores for the pattern paired with the reward on 90% and 10% of the conditioning trials for low, medium and high impulsive groups. B) Percentage of low, medium and high impulsive participants that were aware of the conditions of the experiment (i.e., Task Knowledge), that identified the pattern paired with the reward on 90% (i.e., 90% Pattern Recognition) and 10% (i.e., 10% Pattern Recognition) of the conditioning trials. C) Mean number of cognitive estimation errors for low, medium and high impulsive participants across the six blocks of trials during conditioning.

As previously noted, performance on the counting task was assessed for low, medium and high impulsive participants using a 3 (Impulsivity) X 6 (Trial Block) repeated-measures ANOVA with Trial Block as the within-subjects factor and Impulsivity as the between-subjects factor. As shown in Figure 6 C, there was an overall effect of Trial Block ($F(5, 175) = 3.85$, $p < .05$), and pairwise comparisons revealed that

Trial Block 3 had significantly more errors ($p < .05$) than the other Trial Blocks. There was no significant Impulsivity X Trial Block ($F(10, 352) = .45$, $p = .92$) interaction. Also, there was no overall effect of Impulsivity across the six trial blocks, ($F(2, 177) = .50$, $p = .61$).

Impulsivity, Preference Conditioning and Explicit Memory

Table 9 A presents Impulsivity and CPP scores for the Task Knowledge, 90% Pattern Recognition and 10% Pattern Recognition groups. Table 9 B presents Impulsivity and CPP scores for the No Task Knowledge, No 90% Pattern Recognition and No 10% Pattern Recognition groups. Three different repeated-measures ANOVA's (one for each of the knowledge categories) were used to assess whether for the Task knowledge, 90% and 10% Pattern Recognition groups had different preference scores for the low, medium and high impulsivity groups. Results of the ANOVA's are found in Appendix G.

Table 9 Relationship between impulsivity (defined by the BIS-11/EIQ composite score) and knowledge of experimental conditions for the Conditioned Pattern Preference (CPP) task.

A)Mean CPP scores (SEM) for participants that were aware of the conditions of the experiment (i.e., Task Knowledge), that correctly identified the pattern paired with the reward on 90% (i.e., 90% Pattern Recognition) and 10% (i.e., 10% Pattern Recognition) of the conditioning trials. B) Mean CPP scores (SEM) for the pattern paired with the reward on 90% and 10% of the conditioning trials for participants that were unaware of the conditions of the experiment (i.e., No Task Knowledge), that did not correctly identify the pattern with the reward on 90% (i.e., No 90% Pattern Recognition) and 10% (i.e., No 10% Pattern Recognition) of the conditioning trials.

A

		Preference for the 90% Pattern			Preference for the 10% Pattern		
		Task Knowledge	90% Pattern Recognition	10% Pattern Recognition	Task Knowledge	90% Pattern Recognition	10% Pattern Recognition
Impulsivity	Low	6.92 (1.40)	6.80 (0.72)	6.15 (0.88)	5.50 (1.26)	5.61 (0.79)	4.01 (0.97)
	Medium	8.33 (1.01)	8.65 (0.64)*	7.01 (0.79)	3.17 (1.12)	3.38 (0.71)*	3.13 (0.86)
	High	8.33 (1.14)	7.00 (0.99)	6.50 (1.04)	5.50 (1.26)	4.75 (1.09)	4.50 (1.15)
	Total	7.86 (1.18)	7.48 (0.78)	6.55 (0.90)	4.72 (1.21)	4.58 (0.86)	3.88 (0.99)

B

		No Task Knowledge	No 90% Pattern Recognition	No 10% Pattern Recognition	No Task Knowledge	No 90% Pattern Recognition	No 10% Pattern Recognition
Impulsivity	Low	5.95 (0.54)	6.04 (1.05)	6.65 (1.04)	5.50 (1.54)	4.93 (1.15)	6.84 (1.15)
	Medium	6.51 (0.39)	5.48 (0.74)	7.51 (0.61)	3.17 (1.11)	5.01 (0.82)	4.79 (0.68)
	High	5.30 (0.79)	6.07 (0.82)	6.68 (0.86)	5.50 (1.26)	6.71 (0.91)	6.41 (0.95)
	Total	5.92 (0.57)	5.86 (0.87)	6.95 (0.84)	4.72 (1.30)	5.55 (0.96)	6.01 (0.93)

*$p < .05$

The Emotional Stroop task

A 2 (Sex) X 4 (Colours) repeated-measures ANOVA was used to examine the mean number of errors as well as reaction times (RT) made by female and male participants in responding to each of the four colours used in the Emotional Stroop task (i.e., blue, green, red and yellow).

There was an overall effect of colour for the mean number of errors made on the Emotional Stroop task ($F(3,166) = 26.48$, $p < .001$). The blue ($M = .49$, $SE = .10$) colour condition yielded the least number of errors for participants followed by green ($M = 2.05$, $SE = .21$), red ($M = 1.12$, $SE = .13$) and finally yellow ($M = 1.55$, $SE = .14$). The interaction of Colour X Sex was not significant, $F(3, 166) = 1.90$, $p = .13$). Furthermore, there was no significant difference between female and male participants ($F(2,167) = 1.23$, $p = .29$) on the mean number of errors made on the blue (female, $M = .50$, $SE = .12$; male, $M = .40$, $SE = .16$), green (female, $M =1.68$, $SE = .21$; male, $M = 2.44$, $SE = .32$), red (female, $M = 1.02$, $SE = .13$; male, $M = 1.25$, $SE = .20$) and yellow (female, $M = 1.35$, $SE = .15$; male, $M = 1.63$, $SE = .23$) colours.

There was a significant effect of colour on mean RT (msec) ($F(3,177) = 51.05$, $p < 0.01$) in that the blue colour yielded the fastest responses ($M = 708.86$, $SE = 9.82$), followed by red ($M = 732.53$, $SE = 9.08$), yellow ($M = 734.52$, $SE = 9.13$) and finally green ($M = 773.62$, $SE = 9.61$). Furthermore, there was no overall effect of Sex on RT for the four colour conditions ($F(1,179) = 0.01$, $p = 0.97$). That is, there was no significant difference between female and male RT's on the blue (female, $M = 711.74$, $SE = 10.80$; male, $M = 705.99$, $SE = 16.40$), green (female, $M = 767.98$, $SE = 10.57$; male, $M = 779.25$, $SE = 16.05$), red (female, $M = 732.00$, $SE = 9.99$; male, $M = 733.05$, $SE = 15.17$) or yellow (female, $M = 736.64$, $SE = 10.04$; males, $M = 732.40$, $SE = 15.25$) conditions.

A 2 (Sex) X 3 (Impulsivity) X 3 (Word Category) repeated-measures ANOVA was used to analyze Number of Errors as well as RT (msec) on the Emotional Stroop task. Results are summarized in Table 9.

Table 10 Repeated-Measures ANOVA results for number of errors and mean RT (msec).

Multivariate Tests for Mean Number of Errors			
Effect	F	Hypothesis df	Sig.
Word Category	142.314	2.000	.000
Word Category X Sex	.063	2.000	.939
Word Category X Impulsivity	.533	4.000	.711
Word Category X Sex X Impulsivity	.697	4.000	.594
Tests of Between-Subjects Effects for Mean Number of Errors			
Source	Df	F	Sig.
Sex	1	5.068	.026
Impulsivity	2	1.045	.354
Sex X Impulsivity	2	.522	.594
Error	167		

Multivariate Tests for Reaction Time (msec)			
Effect	F	Hypothesis df	Sig.
Word Category	1.709	2.000	.184
Word Category X Sex	.345	2.000	.709

Word Category X Impulsivity	.543	4.000	.704
Word Category X Sex X Impulsivity	1.666	4.000	.158

Tests of Between-Subjects Effects for RT (msec)

Source	Df	F	Sig.
Sex	1	.007	.933
Impulsivity	2	1.024	.361
Sex X Impulsivity	2	1.992	.140
Error	167		

There was an overall effect of word category. Pairwise comparisons revealed that participants made more errors for the positive (*M* = 12.04; *SE* = .25) and negative (*M* = 10.88; *SE* = .21) words compared to the neutral (*M* = 8.44; *SE* = .26) words.

Furthermore, there was an overall effect of Sex on the mean Number of Errors for each word category but no Sex X Word Category interaction. That is, males made more mean errors across the three word conditions than females, as shown in Figure 7 A.

There was no effect of Word Category on RTs and no Word Category X Sex interaction Similarly, there was no effect of Sex on the mean RT for the positive, negative and neutral word categories, as shown in Figure 7 B.

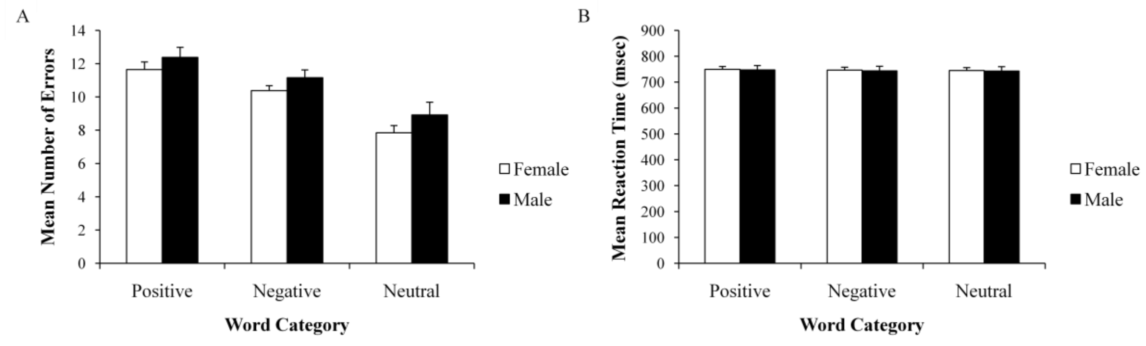

Figure 7 Relationship between Sex and performance on the Emotional Stroop task.

A) Mean number of errors in responding to the positive, negative and neutral words for the low, medium and high impulsive groups. B) Mean reaction time (msec) to respond to the positive, negative and neutral words for the low, medium and high impulsive groups.

Impulsivity and Emotional Stroop task

There was no overall effect of Impulsivity and no significant Word Category X Impulsivity interaction for mean number of errors. These data are shown in Table 8 and Figure 8 A. As shown in Table 8 and Figure 8 B, there was also no effect of Impulsivity on mean RT.

BIS-11 subscales and Emotional Stroop task

A multivariate ANOVA was used to examine how the four difference BIS-11 subscales affected mean RT and Number of Errors made on the Emotional Stroop task. None of the subscales showed an effect on participant RT or Errors made. These data are presented in Appendix .H

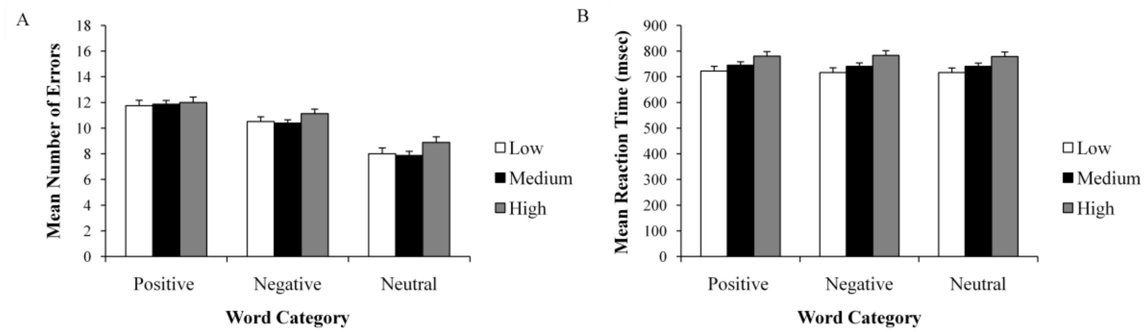

Figure 8 Relationship between Impulsivity (defined by the BIS-11/EIQ composite score) and performance on the Emotional Stroop task.

A) Mean number of errors in responding to the positive, negative and neutral words for the low, medium and high impulsive groups. B) Mean reaction time (msec) in responding to the positive, negative and neutral words for the low, medium and high impulsive groups.

The Probabilistic Reversal Learning (PRL) task

PRL and Gender Effects

A one-way ANOVA revealed no significant difference between female and male participants in their mean RT's on the PRL task ($F(1,181) = 1.62$, $p = .20$), as shown in Figure 9 A.

Two different chi-square tests (one for each stage) were used to examine whether there were different proportions of female and male participants that reached Acquisition and Reversal criteria for the PRL task (i.e., 6 out of 10 correct responses). For the Acquisition stage of the task, there was a significant difference in the proportion of female and male participants that successfully learned the rewarded contingency ($\chi^2(1, N = 182) = 5.76$, $p < .05$). Participants that did not meet acquisition criteria were subsequently excluded from analyses that included the acquisition and reversal stages. There was also a significant difference in the proportion of female and male participants that successfully learned the rewarded contingency in that a higher proportion of females successfully learned the rewarded contingency in the reversal stage of the task, ($\chi^2(1, N = 164) = 4.08, p < .05$). Participants that did not reach reversal criteria were also excluded from further analyses on the reversal stage. These data are shown in Figure 9 B.

A multivariate ANOVA for each stage (i.e., Acquisition, Reversal) with Sex and Impulsivity as between-subjects factors was used to examine Errors to Criterion, and Total Errors for each stage (i.e., Acquisition, Reversal) of the PRL task.

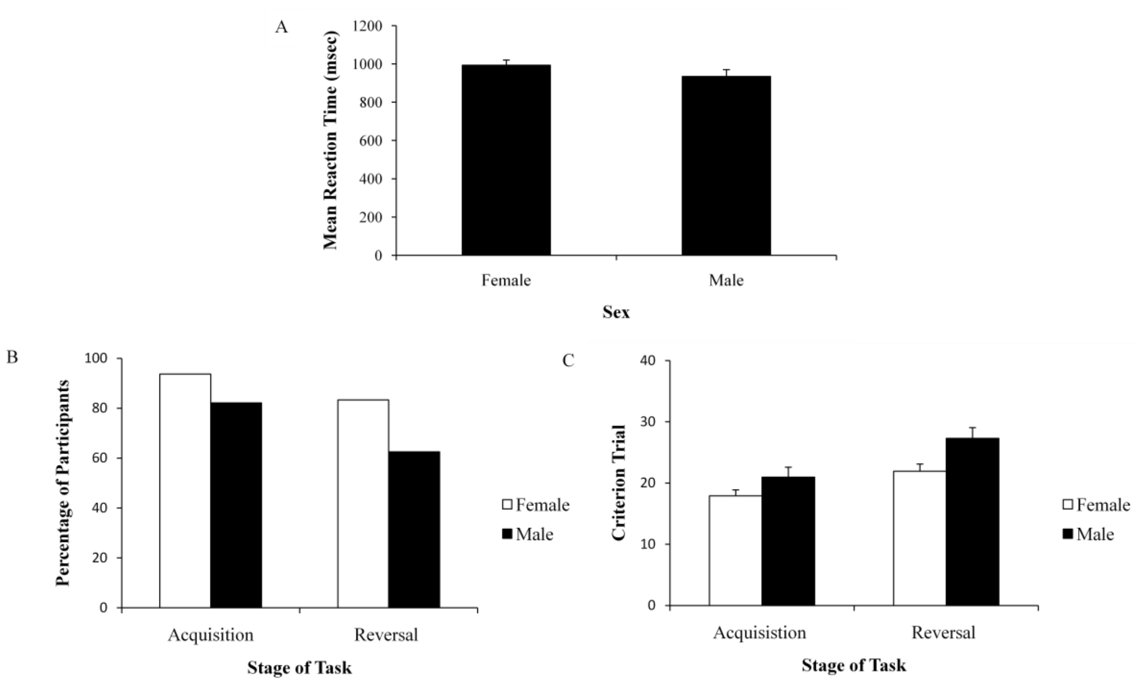

Figure 9 Performance of female and male participants on the Probabilistic Reversal Learning (PRL) task.

Mean reaction time (msec) for female and male participants on the PRL task. B) Percentage of female and male participants that met criterion (i.e., 6 out of 10 correct responses) for the Acquisition and Reversal stages of the task. C) Trial number at which criterion (i.e., 6 consecutive correct responses) was met for female and male participants in the Acquisition and Reversal stages of the task.

For those that met the Acquisition criterion, there was no significant difference between female and male participants in Errors to Criterion, ($F(1,147) = .22$, $p = .64$) or Total Errors ($F(1,147) = .32$, $p = .57$) in the Acquisition stage of the PRL task. Similarly, for those that met Acquisition and Reversal stage criteria, there was no significant effect of Sex for Errors to Criterion, ($F(1,138) = 1.04$, $p = .31$) or Total Errors ($F(1,138) = .29$, $p = .59$) in the Reversal stage of the PRL task. These data are shown in Figure 9 C.

Including only the subjects that met reversal criterion, a 2 (Sex) X 2 (Stage of Task) X 8 (Trial Block) repeated-measures ANOVA revealed no overall effect of Sex on Errors ($F(4, 137) = .44$, $p = .77$). Moreover, female and male participants did not differ in the number of errors made prior to reaching criterion in the Acquisition (female, M = 3.05, SE = .22; male, M = 3.17, SE = .42) or Reversal (female, M = 6.23, SE = .49; male, M = 6.28, SE = .83) stages. Furthermore, female and male participants did not differ in the total number of errors in the Acquisition (female, M = 19.25, SE = 0.94; male, M = 19.09, SE = 1.34) or Reversal (female: M = 19.57, SE = .78; male, M = 19.53, SE = 1.13) stages of the PRL task. A small difference in error rate across trial blocks (each block consisted of 10 trials) approached statistical significance (Figure 10; $F(1,140) = 4.08$, p = .054).

Impulsivity and Performance on PRL task

A one-way ANOVA revealed no effect of Impulsivity on mean RT on the PRL task ($F(2,181) = 1.19$, $p = .30$). That is, there was no significant difference in RT for low

(M = 925.37, SE = 31.19), medium (M = 991.33, SE = 29.01) and high (M = 993.32, SE = 53.79) impulsive groups. Table 9 shows the relationship between impulsivity and performance on the PRL task.

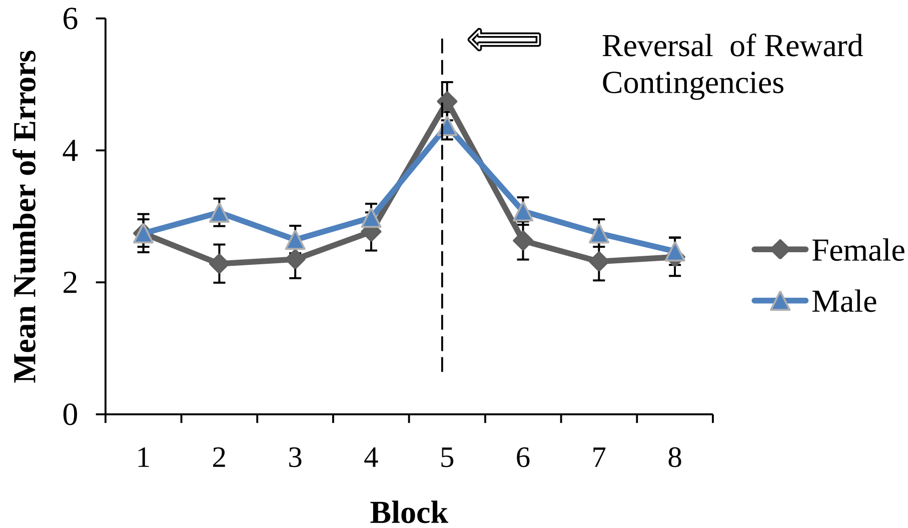

Figure 10 Mean number of errors across blocks of trials for female and male participants in the Probabilistic Reversal Learning (PRL) task.

Each block consists of 10 trials; blocks 1-4 represent the Acquisition stage and blocks 5-8 represent the Reversal stage of the PRL task.

A two-way chi-square test was used to determine if there was a difference in the proportion of low, medium and high impulsive participants that reached Acquisition and Reversal criteria on the PRL task. There was a difference in the proportion of low (n = 44), medium (n = 83) and high (n = 37) impulsive participants that reached Acquisition (χ^2 (1, N = 182) = 4.70, p = .03). This difference was not apparent for the low (n = 36), medium (n = 74) and high (n = 30) impulsive subjects in the Reversal (χ^2(2, *N* = 164) = 1.04, *p* = .59) stage.

There was a significant effect of Impulsivity on the number of errors made in the Acquisition (*F*(2,147) = 3.38, *p* < .05) but not the Reversal (*F*(2,138) = .84, *p* = .59) stage of the PRL task. Pairwise comparisons revealed that for the Acquisition stage (i.e., learning errors), there was a significant difference between low and medium (*p* < .05) as well as low and high (*p* < .05) Impulsivity groups. There was no significant effect of Impulsivity on the number of errors made prior to reaching criterion in the Acquisition (*F*(2,147) = .64, *p* = .70) or Reversal stages (*F*(2,138) = 1.47, *p* = .19) of the PRL task. These data are shown in Table 11.

A 3 (Impulsivity) X 8 (Trial Block) repeated-measures ANOVA was used to examine the difference between low, medium and high impulsive groups in the number of errors made across Trial Blocks (each block consisted of 10 trials) for the PRL task, as shown in Figure 11. There was no overall effect of Impulsivity (*F*(2, 179) = 1.70, *p* = .18) on the mean number of errors made by high impulsive participants across the 8 trial blocks.

Table 11 Relationship between impulsivity and performance on the Probabilistic Reversal Learning (PRL) task.

Mean number (SEM) of total errors and errors to criterion for low, medium and high impulsive groups in the acquisition and reversal stages of the task.

	Impulsivity		
	Low	Medium	High
Acquisition Criterion Met (% of participants)	95.65 (n = 44)	91.21 (n = 83)	82.22 (n = 37)
Reversal Criterion Met (% of participants)	81.81 (n = 36)	89.16 (n = 74)	81.08 (n = 30)
Errors to Criterion Acquisition Stage	2.58 (0.37)	2.97 (0.73)	2.71 (0.47)
Errors to Criterion Reversal Stage	4.94 (0.65)	5.59 (0.46)	6.77 (0.72)
Errors Acquisition Stage	22.73 (1.55)	18.40 (1.13)	16.05 (1.69)
Errors Reversal Stage	20.89 (4.50)	18.26 (0.97)	17.10 (1.52)

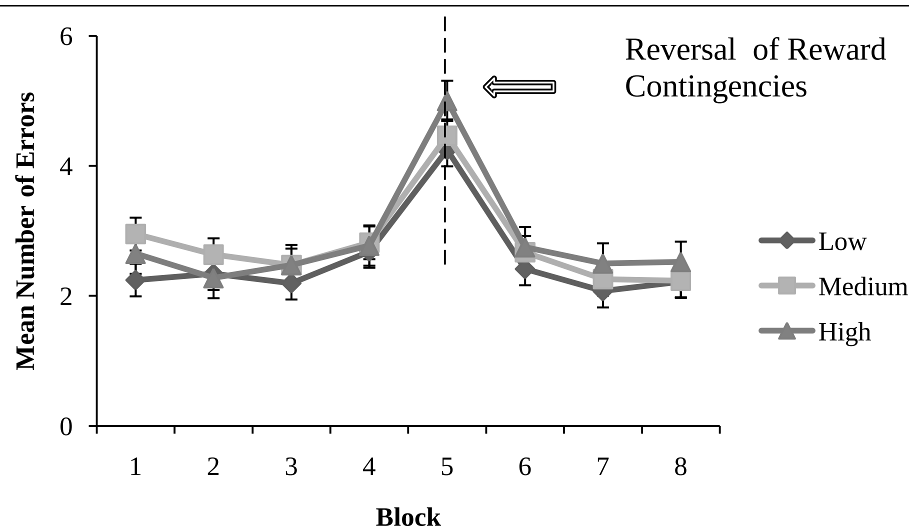

Figure 11 Mean number of errors across blocks of trials for low, medium and high impulsive participants in the PRL task.

Each block consists of 10 trials; blocks 1-4 represent the Acquisition stage and blocks 5-8 represent the Reversal stage of the PRL task.

The composite score of Impulsivity (as a continuous variable) did not significantly predict errors prior to reaching criterion in the Acquisition stage, $b = -.08$, $t(147) = -.46$, $p = .64$. Impulsivity significantly predicted perseverative errors in the Reversal stage, $b = .16$, $t(154) = 2.01$, $p < .05$. Impulsivity also explained a significant proportion of variance in perseverative errors, $R^2 = .03$, $F(1, 153) = 4.05$, $p < .05$. Furthermore, Impulsivity significantly predicted how many errors were made in the Acquisition, $b = -2.02$, $t(180) = -2.49$, $p < .05$, but not the Reversal, $b = -.69$, $t(181) = -1.01$, $p = .31$, stage of the PRL task.

BIS-11 subscales and Performance on the PRL task

A multivariate ANOVA for each stage (Acquisition, Reversal) was used to examine how the four different BIS-11 subscales (i.e., Attention, Motor, Self-Control and Cognitive) affected the Errors to Criterion as well as the Mean Errors for the Acquisition (i.e., learning errors) and Reversal (i.e., perseverative errors) stages of the PRL task. There was no overall effect of any of the subscales on Errors in both stages of the PRL task. These data are presented in Appendix I.

Summary of findings

In sum, male subjects made more cognitive estimation errors in the CPP task and participants with some awareness of task conditioning revealed significantly higher CPP preference scores than participants that were not in any of those groups. There was however a significant interaction of Sex and Pattern. That is, the preference formation was stronger for males than it was for females. The CPP is a task with relatively low demand awareness; when subjects were asked on why they preferred or disliked the patterns, 87.4% of subjects attributed their preference to the physical characteristics of the patterns and not the experimental contingencies of the conditioning trials. When asked to identify the patterns they believed to be associated most with the red or black ball, 68.7% were incorrect in their choices for the red ball and 73.6% of subjects made incorrect choices for the black ball. Furthermore, the medium impulsive group accounted for the majority of the subjects that had some knowledge of the experimental conditions.

Overall, there was a higher proportion of male subjects that had explicit knowledge of the experimental conditions. Subjects that were considered to have some explicit knowledge of experimental conditions showed a higher preference formation for the pattern paired with the reward on 90% of the conditioning trials. Although there was no overall effect of impulsivity, the medium impulsive group displayed the strongest preference formation (highest score for the 90% pattern and lowest score for the 10% pattern) compared to the low and high groups.

There was an overall effect of Sex on the mean Number of Errors for each word category in the Emotional Stroop task. That is, males made more mean errors across the three word conditions than females. Furthermore, there was an overall effect of Word Category in that participants made more errors for the emotional words (positive and negative) than the neutral words.

For the PRL task, more female participants successfully learned the rewarded contingency for both stages of the task and more participants in the high impulsive group did not meet criterion for the Acquisition stage while approximately 14% of low impulsive subjects did not meet reversal criterion. Furthermore, high impulsive subjects made more overall errors in the Acquisition stage but not Reversal stage and impulsivity accounted for a significant amount of the variance in the Acquisition stage. Finally, impulsivity accounted for a significant amount of the variance for the number of perseverative, but not learning, errors in the PRL task.

Chapter 4

Discussion

Conditioned Pattern Preference task

The main findings for the CPP task are summarized in the following points: 1) overall, participants showed a significant preference formation, 2) participants that had some explicit knowledge of the task showed a stronger conditioned preference , 3) males exhibited significantly worse working memory than females, 4) there was a higher proportion of males than females that had some knowledge of the experimental conditions, and 5) there was no effect of impulsivity on preference scores, although the medium impulsivity group showed a significant pattern preference that was absent in the other two groups.

In line with previous studies using this task, there was an overall preference for the pattern paired with the reward on 90% of the conditioning trials, and there was no difference between female and male participants on this preference formation (Balodis, Johnsrude & Olmstead, 2007). The significant preference was lost when participants who had explicit knowledge of the task were eliminated from the analysis, a finding that contradicts previous reports. That is, Balodis et al. (2007) did not report any difference in preference formation between those who explicitly related their preferences to the pattern and those who did not.

Knowledge of the patterns associated with the reward is an example of contingency awareness, defined as the explicit knowledge of the conditioned stimulus/unconditioned stimulus association. The question of whether contingency awareness is necessary for preference conditioning is highly debated in the literature. Some authors report that contingency awareness is essential for conditioning while others argue that conditioned responses can occur in contingency-unaware subjects (Dawson, Rissling, Schell & Wilcox, 2005; Lovibond & Shanks, 2002). The human CPP task appears to rely on contingency awareness for preference formation, at least as assessed in the current study.

In this study, explicit knowledge was assessed by asking participants why they preferred one pattern over the others; explicit knowledge was reflected as an understanding that pattern preferences were due to reward contingencies during conditioning. In addition, this study assessed recognition of the patterns associated with reward and non-reward. More specifically, after subjects were asked why they liked a particular pattern, they were asked to identify which of the six patterns were paired most frequently with the red or black ball. There was a higher proportion of subjects that recognized the conditioned stimuli than subjects that had contingency awareness. That is, not all subjects that had contingency awareness recognized which patterns were associated with the red and black balls. This suggests that contingency awareness and recognition are separate processes. Bechara and colleagues (1995) argue that individuals can acquire both implicit associations and contingency awareness and that those two systems are different. Implicit associations refer to a participant's subjective experience of suddenly identifying a contingency. This has also been referred to as 'insight' in some studies (McKell Carter et al, 2006). Insight can be defined as the subjective phenomenon by which the information suddenly enters consciousness (Seifert, Meyer, Davidson, Patalano, & Yanive, 1995). Insight would therefore correspond to the recognition of patterns associated with the red and/or black ball. In this study, 13% of total subjects (i.e., 22 subjects) had contingency awareness. There were 54 subjects that displayed 'insight, of which 16 also had contingency awareness, thus there was approximately 30% overlap between contingency awareness and 'insight'. Both of those groups showed preference formation while the subjects that did not have contingency awareness or 'insight' did not. There haven't been any studies assessing the role of insight on preference formation, although this study indicates that it might be as predictive of preference formation as is contingency awareness since not having either appears to predict a lack of preference formation.

In the CPP, a higher proportion of female subjects recognized the patterns paired with the red and black balls (i.e., males were likely in this study to have 'insight'). Working memory refers to an ability to manipulate information in memory while performing a task. There is no evidence to suggest that females and males differ in working memory ability although males have been shown to outperform females in visuo-spatial memory (Makarek et al, 1993; 1995; Postam et al, 1998; Voyer et al, 1995).

CPP and Awareness

The role of awareness in preference conditioning is unclear. Mitchell et al, suggest that learning should be found only when participants have conscious awareness of the relevant relations among stimuli since there is no evidence that (truly) unaware conditioning exists. They argue that awareness is even necessary in Pavlovian conditioning of human autonomic responses, for example, a CS (e.g., a light) is paired with an aversive US such as an electric shock. Here, learning is shown by the ability of the CS to increase the participant's skin conductance, a measure of fear or increased anxiety. The skin conductance CRs only appear in participants who are aware of the CS-US contingency (for reviews, see Dawson & Schell 1985; Lovibond & Shanks 2002). Therefore, an awareness of the CS-US contingency is necessary for Pavlovian conditioning to occur (Dawson & Shell 1985). Shock training is evidently different from conditioned preference; in fact, it might be viewed as the reverse process. That is, rewarding (preference) and aversive (fear/shock) effects are known to have common underlying mechanisms (Carlezon & Thomas, 2009). For instance, DA is released equally effectively in the nucleus accumbens core by aversive stimuli, and stimuli conditioned to them. Therefore, the fact that awareness appears to be a necessary factor in preference formation might be due to the fact that it is not entirely dissociable from shock training or fear conditioning.

Considering that the present findings conflict with the previous study, the role of contingency awareness in the CPP remains unclear. There is substantial evidence to suggest that subjective awareness is dissociable from conditioning processes (Berridge, 1996). That is, fundamental reward processes can exist with or without awareness. The most convincing evidence for this is the fact that low doses of morphine produce motivational changes in behaviour without producing a subjective reward in substance abusers (Lamb et al, 1991). Berridge argues that subjective reports may contain false assessments of underlying processes, or even fail to register important reward processes (1996). While in the present sample awareness mediates preference formation this was not the case in previous studies where subjects that did not report subjective awareness displayed preference formation (Balodis, et al, 2007).

There has been extensive research on the role of awareness on conditioning. Recently, a very comprehensive review has addressed the dichotomous view of implicit and explicit learning (Shanks, 2010), noting that studies on amnesic patients provide interesting support for the importance of awareness. In brief, conditioning is assumed to be a "procedural" learning task and awareness is assumed to depend on "declarative" memory (Squire, 1994). Furthermore, amnesia is a selective deficit in declarative memory. Therefore amnesia patients should show normal conditioning along with impaired contingency awareness. Basically, they should be more likely than controls to show conditioning without awareness. However, in various conditioning tasks, amnesic patients performed comparably to controls and showed an accurate knowledge of the cue–outcome contingencies, as well as insight into the importance of cues for their predictions (Lovibond & Shanks, 2002; Kinder & Shanks, 2001; Daum, Channon & Gray, 1991). Hence, there was no dissociation between implicit learning and explicit awareness and no evidence of conditioning in the absence of awareness. Shanks concludes that there is no direct evidence in the experimental literature of unconscious learning (2010). Consequently, it is likely that awareness is a necessary condition for all forms of learning, including conditioning.

CPP as a measure of reward sensitivity

In the place conditioning paradigm, the primary motivational properties of a drug or non-drug treatment serve as an unconditioned stimulus (US). It continues to be one of the most popular models to study the motivational effects of drugs and non-drug treatments in experimental animals. The UCS is repeatedly paired with a previously neutral stimulus which acquires, (during the course of conditioning), secondary motivational properties. Consequently, the UCS acts as a conditioned stimulus (CS) which then elicits 'approach' when the animal is exposed to these stimuli. Thus, behavioural approach is conceptualized as a motivational system which responds to rewarded stimuli (Corr, 2004). In contrast, the behavioural inhibition system is considered as an attentional system which is sensitive to punishment or non-reward, which elicits inhibition of approach responses. Consequently, conditioned preference/aversion is a reliable method for assessing the reinforcing properties of various rewards and punishments (Tzschentke, 2007).

The CPP might not be ideally suited for measuring reward sensitivity. One important aspect of reward sensitivity is anticipation (Dresler et al, 2009). In short, anticipation of a reward during a Monetary Incentive Delay Task elicited activation in the ventral striatum, the amygdala and the orbitofrontal cortex (known reward circuitry).

Furthermore, the authors were able to show an increased behavioural approach in individuals with increased reward sensitivity (as measured by the SPSRQ). Therefore, there was increased brain activation during reward anticipation. The CPP task does not have an anticipatory measure of reward which might make it unsuitable as a direct measure of reward sensitivity. Furthermore, it is unclear how punishments would affect preference formation (or aversion) in the CPP task. Therefore it would be useful to have measures of anticipation and perhaps even punishment to determine generalizability of these findings for reward sensitivity.

Impulsivity and CPP

Overall, there was no significant effect of impulsivity on preference formation although the medium impulsive group showed a significant CPP that was not present in the other two groups. Considering that contingency awareness affects performance, it is not surprising that the medium impulsive group also accounted for the highest proportion of subjects displaying contingency awareness. Furthermore, the medium impulsive group accounted for the highest proportion of subjects with 'insight' or recognition of the red and black balls.

The selective increase in preference conditioning in the medium impulsive group can be interpreted as by an inverted-U relationship between cognitive performance (i.e., working memory, set-shifting) and individual differences in trait impulsivity (Cools, Lewis, Clark, Barker & Robinson, 2007; Cools, Sheridan, Jacobs, D'Esposito, 2007;

Vijayraghavan et al., 2007). While impulsive behaviour is often defined as impaired cognitive inhibition which is rapid, spontaneous, unplanned and potentially maladaptive, it can also refer to “response-ready” individuals (who are hypervigilant, rapid-scanning, and hyperactive/hyper-responsive) (Enticott, Ogloff, & Bradshaw, 2006). This would be in contrast to their low impulsive counterparts who might be “problem-solvers” but who do not act quickly enough to escape a threat (Jensen et al., 1997). In that view, low impulsivity like high impulsivity may also be maladaptive. Therefore, having a medium level of impulsivity may be optimal for various cognitive abilities. This is illustrated in the medium impulsive subjects’ preference formation, contingency awareness and pattern recognition on the CPP task.

The underlying mechanisms of low and high impulsivity are likely mediated by the D1 receptor which mediates concentrations of DA in the PFC. For instance, cognitive impairments (such as working memory) are linked to insufficient as well as excessive D1 receptor stimulation in the PFC (William & Goldman-Rakic, 1995; Arnsten, 1998; Sawaguchi et al., 1994; Murphy et al., 1996). The development of ADHD has been linked to maturational changes in the dopamine system, particularly D1 signalling (Andersen & Teicher, 2000; Diaz, Heijtz et al., 2004). In the PFC, the D1 family of DA receptors is 20 times more abundant than D2-type receptors and has an extensive role in cognitive functions such as working memory (Goldman-Rakic, 2000; McNab et al., 2009). Furthermore several DA-related genes (i.e., DAT1 and DAT4) are also associated with ADHD and play an important role in the regulation of attention and motor behaviour, with a specific role for the D1 receptor (Seeman & Madras, 1998; Davids et al., 2003; Misener et al., 2004; Levy, 2008; Laurin et al., 2008). Basically, the balance in D1 signalling in the brain is due to an excessive, as well as insufficient, D1 receptor stimulation, which impairs prefrontal cognitive functioning (Arnsten & Li, 2005; Williams & Castner, 2006). This might help explain how dopamine is involved in low as well as high impulsive behaviour. Therefore, the finding that low and high impulsive groups in this study performed similarly is consistent with the idea that impulsivity follows an inverted-U shape in affecting cognitive performance (i.e., working memory and attention).

Furthermore, D1-receptor activation, when in close proximity to NMDA receptors, prolongs both LTP and LTD (Chen et al., 1996; Otmakhova and Lisman, 1998; Bach et al., 1999; Bailey et al., 2000; Gurden et al., 2000; Huang et al., 2004). Muly et al., argue that D1 receptor stimulation enhances excitatory transmission to both pyramidal cells and interneurons, but the enhancement is more effective on pyramidal cells because of the closer contacts with dopaminergic axon terminals (Muly, Szigeti & Goldman-Rakic, 1998). On pyramidal neurons, the spine may act as a diffusion barrier, while on interneurons D1 receptor synapses are located on the shaft allowing for more diffusion of second messengers (Murphy, Arnsten, Goldman-Rakic, et al., 1996; Zart et al., 1997). Thus, DA has no clear excitatory or inhibitory function. A dysfunction in this system therefore may contribute to a maladaptive low or high impulsivity which in turn affects prefrontal cognitive functions such as contingency awareness and working memory.

Working Memory and Impulsivity

In the CPP task, there was no significant difference between the low, medium and high impulsive groups on working memory. Inhibitory control and working memory impairments represent distinct deficits in ADHD populations but some authors have argued that they could be dual manifestations of a common pathologic mechanism (Castellanos and Tannock, 2002). Nevertheless, this study did not employ a pathologically impulsive sample, therefore it is not possible to determine if the CPP is sensitive to this distinction. That is, the working memory component of the CPP (primarily used as a distractor from the experimental conditions) does not appear to be disrupted by non-pathological levels of impulsivity.

Emotional Stroop

In this study, there was an effect of word condition in the emotional stroop task in that the neutral words yielded fewer errors than the emotional words (positive and negative). There was no overall effect of sex on latency to respond or number of errors. Furthermore there was no overall effect of impulsivity across word categories. Therefore this version of the emotional Stroop task is not sensitive to difference in impulsivity in a non-pathological population with impulsivity measured by the BIS-11 and EIQ. This lack of impulsivity effect is consistent with the extensive literature using different versions of the Stroop task on various populations.

The Stroop task has been used extensively in pathological populations and has not yielded consistent findings. For instance, there is no difference in cognitive interference (as measured by RT and errors) between ADHD populations and age-matched controls in a regular Stroop task (Schwartz & Verhaeghen, 2008). In that study, both ADHD individuals and controls took 1.7 times longer to respond to stimuli in the color-word condition than the color condition. This lack of difference between ADHD individuals and controls is supported in two meta-analytic studies on ADHD including Stroop tasks and executive functioning (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; van Mourik, Oosterlaan, & Sergeant, 2005). In brief, with respect to Stroop tasks, individuals with ADHD showed worse/slower reaction times than normal controls on all three cards of the Stroop (the first two require reading colour names and the third is the actual interference card), not just on the interference card. When controlling for performance on the colour card, the effect size for the colour word card was no longer significant. Overall, the evidence is consistent that ADHD subjects do not perform differently than their age-matched controls in the Stroop task. This suggests that the difference between ADHD and normal controls is a general decrement in performing the Stroop, not related to the general cognitive or attentional interference assessed in the Stroop. This implies that the Stroop task is not sensitive to differences in impulsivity, at least in ADHD populations.

The BIS-11 has been extensively used in conjunction with the Stroop task in many pathological groups (i.e., gambling, drug abuse, psychotic disorders). In alcoholic individuals, there appears to be a subgroup that is determined as impulsive (cluster-B) and this impulsivity is thought to contribute to their substance abuse. Cluster-B personality disorder individuals with alcoholism have a higher subjective (as measured by the BIS-11) impulsivity than the alcoholics without the comorbidity (Dougherty, Moeller, Steinberg, Marsh, Hines, & Bjork, 1999). Interestingly, their performance on the Stroop task was not different from controls (Dom, De Wilde, Hulstijn, van den Brink, & Sabbe, 2006). Thus, the authors argue that the standard Stroop test is not sensitive to mild cognitive impairment.

More consistent findings have been produced with an emotional or alcohol-specific Stroop task (i.e., including alcohol-related words (Bauer & Cox, 1998; Lusher, Chandler, & Ball, 2004)). PG subjects have been shown to be more impulsive than non-gamblers as measured by the BIS-11 (Saez-Abad, Bertolin-Guillén, 2008). In a modified Stroop task using gambling related words only the gamblers showed cognitive biases for gambling-related information compared to healthy controls (McCuster & Gettings, 1997).

The emotional Stroop task has been the most widely used task to examine attentional bias to emotionally salient stimuli. It is often used as a measure of attentional bias to stimuli related to an individual's current pathology. Attentional bias is measured by the reaction time to name the 'relevant emotional' words. It is expected that 'relevant emotional' words will yield slower responses than control words for those populations. Waters et al., found that smokers are slower to respond to words which follow smoking related words compared to words which follow neutral words (2005). This 'carry-over' effect was robust and only extended to the previous word. Furthermore, heroin addicts showed the same effect with heroin-related words (Franken, Stam, Hendriks, 2003). These studies only reported reaction time so it is not known if the 'carry-over' effect also generalizes to number of errors.

Given that neither pathological nor non-pathological populations show deficits in stroop performance for high impulsives, the lack of interference in the high impulsive group (as indicated in this experiment) for emotional words is consistent with previous findings. Since this study did not assess a pathological population, it is not surprising that the self-report measures of impulsivity did not yield any significant differences in Stroop performance. Furthermore, it appears that unless the Stroop task is geared specifically for a tested population (with population specific words) it is difficult to interpret and generalize findings. Perhaps for non-pathological student populations it would be more sensible to use a Stroop task with stress-related words (Woodfield, Jones, & Martin, 1995). Nevertheless, the fact that there was no significant effect of impulsivity on emotional Stroop performance in this non-pathologic sample is consistent with previous studies using the original Stroop version as well as modified Emotional Stroop tasks.

Probabilistic Reversal Learning

In this study, there were a higher proportion of female subjects that met acquisition as well as reversal criteria in the PRL task. Furthermore, males that learned the initial contingency were significantly worse in doing so; in other words, males met acquisition criterion at a later stage than females. In the acquisition stage there were approximately 10% fewer high impulsive subjects that met acquisition criterion than the low and medium impulsive groups. Conversely, 14% of low impulsive subjects that had initially acquired the pairing did not meet criterion for the reversal stage. Next, while there was no significant difference in learning errors (acquisition stage) between the three impulsivity groups, the high impulsive group had significantly more perseverative errors (reversal stage). Finally, there was a significant effect of impulsivity on total errors in the acquisition (but not reversal) stage, in that the low impulsivity group had the highest number of errors and the high impulsive group had the lowest.

It is not clear why in this sample, female subjects performed better on the PRL task than male subjects. It is possible that there are gender differences in the serotonergic or dopaminergic system, which mediate reversal learning (Clark, Cools, & Robbins, 2004), although there is no direct evidence to support this.

One of the main findings in the PRL task was that more high impulsive subjects failed meet the initial acquisition of probabilistic contingencies. This protocol did not allow for an extended learning period (thus not allowing every subject to learn the initial contingencies) which might contribute to this reported difference. From the subjects that were included in the analyses it appears that there is no overall difference (between the impulsivity groups) in the number of reversals made. However, fewer high impulsives learned the initial contingency while fewer low impulsives met the reversal criterion. This is inconsistent with previous results (Franken et al., 2008) showing that high impulsive subjects (measured by the EIQ) made more perseverative errors in the reversal stage.

In this study high impulsives had the least number of perseverative errors.The 'poor performers' (those that did not reach criterion for acquisition or reversal) were excluded from subsequent analyses which might contribute to these findings. Here, high impulsive subjects were impaired in acquiring the initial pairing while low impulsives were less likely to make the reversal. To date, there is not much literature assessing performance of low impulsive subjects on PRL tasks. Other PRL studies do not report a measure of medium impulsivity to make the contrast between the groups. The findings from the current study suggest that low and high groups perform sub-optimally, consistent with an inverted-U relationship of impulsivity

Generally, more perseverative errors are associated with high impulsivity (Cools, Barker, Sahakian, & Robbins, 2003). Many pathological samples have been assessed on reversal learning tasks. Response perseveration and reward/punishment sensitivity were measured with a probabilistic reversal-learning task in PG's where problem gamblers showed severe response perseveration (de Ruiter, Veltman, Goudriaan, Oosterlaan, Sjoerds, &

van den Brink, 2009). Therefore, PG was related to response perseveration as well as diminished reward and punishment sensitivity. Adults with psychopathy were impaired on the response reversal component but not on the acquisition component of the task (Budhani, Richell, & Blair, 2006). Interestingly, schizophrenia patients and controls performed similarly on the initial acquisition of probabilistic contingencies; however these patients showed substantial learning impairments when the reinforcement contingencies were reversed, and they achieved significantly fewer reversals from matched controls (Waltz & Gold, 2007). In another study, compared to healthy controls, individuals with schizophrenia exhibited poorer overall performance during acquisition, but exploratory analysis revealed that this was only for low reward magnitudes (Weiler, Bellebaum, Brune, Juckel, & Daum, 2009).

In Parkinson's, L-Dopa medication remediates cognitive inflexibility on a reversal learning paradigm but also induces impulsive behaviour on an IGT-type decision-making task (Cools, Barker, Sahakian, & Robbins, 2003). Further, L-Dopa also increases the propensity of Parkinson's patients to gamble irresponsibly which presumably reflects poor impulse control (Gschwandtner, Aston, Renaud, & Fuhr, 2001). Overall, many studies have shown that L-Dopa impairs reversal learning performance in Parkinson's patients. Interestingly, L-DOPA modulates reversal-related brain activity in the nucleus accumbens, but not in the dorsal striatum or the prefrontal cortex indicating that nucleus accumbens is crucial for in the DA-ergic modulation of reversal learning (Cools, Lewis, Clark, Barker, & Robbins, 2007).

The PRL task in the present study was tested on a non-pathological population and did not include levels of reward magnitude. The fact that high impulsive subjects in this study are deficient in a PRL task is consistent with previous studies (Franken, van Strien, Nijs & Muris, 2008). The finding that a significant number of low impulsive subjects did not meet reversal criterion is not consistent with previous literature. It unknown if this deficiency found in the low impulsive group is due to the type of positive feedback (low reward magnitude) provided on correct trials or if excluding the 'poor performers' (those that did not meet criterion) in this study biased the results.

Limitations and Future Directions

This study was conducted on a non-pathological undergraduate population. The mean BIS-11 score for the high impulsive group was not pathological. Nevertheless, the medium impulsive group behaved differently than the low and high impulsive groups in the CPP and PRL tasks. It would be interesting to know if the mean impulsivity scores for the low group are considered pathological. Future studies are needed to address this potentially maladaptive aspect of low impulsivity and if the BIS-11 and EIQ are sensitive to them in an undergraduate student population.

In brief, the results from this study are inconclusive mainly due to the fact that the Stroop task in this study was not specific to an undergraduate population. In the future, it would be useful to assess attentional bias by administering a Stress Stroop, specific for undergraduate populations.

The PRL in this study was not rewarded like other studies (no monetary or gustatory incentives) and it did not include a change in the probability of reward within the study (always 80:20). Some subjects therefore had more practice than others in the acquisition stage (prior to reaching reversal). Perhaps, if once acquisition was met, reversal should have been immediately prompted. Then, all subjects would have had the same exposure to the rewarded contingency prior to reversal. Furthermore, there was only one reversal in this task. Future studies should also include subsequent reversals to assess whether ‘poor starters’ still differ from ‘fast learners’ in the long run.

It is important to note that even though this was not a pathologically impulsive population, there were still differences found in the medium impulsive group’s performance in the CPP and PRL tasks. This is worth exploring in future paradigms of conditioned learning and impulsivity.

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Appendix A

Eysenck Impulsiveness Scale

I7 Questionnaire Participant #__________________

Age ______

Sex______

Instructions: Please answer each question by putting a circle around the "YES" or the "NO" following the questions. There are no right or wrong answers, and no trick questions. Work quickly and do not think too long about the exact meaning of the question.

PLEASE REMEMBER TO ANSWER EACH QUESTION

1. Would you enjoy water skiing? ________________________________YES NO
2. Usually, do you prefer to stick to brands you know are reliable, to trying new ones on the chance of finding something better? _____YES NO
3. Would you feel sorry for a lonely stranger? ______________________YES NO
4. Do you quite enjoy taking risks? ______________________________YES NO
5. Do you often get emotionally involved with your friends' problems? ____YES NO
6. Would you enjoy parachute jumping? __________________________YES NO
7. Do you often buy things on impulse? ___________________________YES NO
8. Do unhappy people who are sorry for themselves irritate you? _____YES NO
9. Do you generally do and say things without stopping to think? ____YES NO
10. Are you inclined to get nervous when others around you seem to be nervous?______________________________________YES NO
11. Do you often get into a jam because you do things without thinking? ____YES NO
12. Do you think hitch-hiking is too dangerous a way to travel? ______YES NO

13. Do you find it silly for people to cry out of happiness? __________YES NO

14. Do you like diving off the highboard? ________________________YES NO

15. Do people you are with have a strong influence on your moods? ___YES NO

16. Are you an impulsive person? ______________________________ YES NO

17. Do you welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional? __________YES NO

18. Does it affect you very much when one of your friends seems upset? ____YES NO

19. Do you usually think carefully before doing anything? ___________YES NO

20. Would you like to learn to fly an aeroplane? ___________________YES NO

21. Do you ever get deeply involved with the feelings of a character in a film, play or novel? ____YES NO

22. Do you often do things on the spur of the moment? _____________YES NO

23. Do you get very upset when you see someone cry? _____________YES NO

24. Do you sometimes find someone else's laughter catching? _______YES NO

25. Do you mostly speak without thinking things out? ______________YES NO

26. Do you often get involved in things you later wish you could get out of? ____YES NO

27. Do you get so 'carried away' by new and exciting ideas, that you never think of possible snags? ______________________YES NO

28. Do you find it hard to understand people who risk their necks climbing mountains? ___________________________YES NO

29. Can you make decisions without worrying about other people's feelings? ____YES NO

30. Do you sometimes like doing things that are a bit frightening? ____YES NO

31. Do you need to use a lot of self-control to keep out of trouble?____YES NO

32. Do you become more irritated than sympathetic when you see someone cry? ________________________________ YES NO

33. Would you agree that almost everything enjoyable is illegal or immoral? ____YES NO

34. Generally do you prefer to enter cold sea water gradually, to diving or jumping straight in? ______________________________YES NO

35. Are you often surprised at people's reactions to what you do or say? ____YES NO

36. Would you enjoy the sensation of skiing very fast down a high mountain slope? ______________________________YES NO

37. Do you like watching people open presents? _____________________YES NO

38. Do you think an evening out is more successful if it is unplanned or arranged at the last moment? _______________________________YES NO

39. Would you like to go scuba diving? ____________________________YES NO

40. Would you find it very hard to break bad news to someone? _________YES NO

41. Would you enjoy fast driving? ________________________________YES NO

42. Do you usually work quickly, without bothering to check? __________YES NO

43. Do you often change your interests? ____________________________YES NO

44. Before making up your mind, do you consider all the advantages and disadvantages? ____YES NO

45. Can you get very interested in your friends' problems? _____________YES NO

46. Would you like to go pot-holing? ______________________________YES NO

47. Would you put off a job involving quite a bit of danger? ____________YES NO

48. Do you prefer to 'sleep on it' before making decisions? _____________YES NO

49. When people shout at you, do you shout back? _________________YES NO

50. Do you feel sorry for very shy people? ________________________YES NO

51. Are you happy when you are with a cheerful group and sad when the others are glum? ______________________YES NO

52. Do you usually make up your mind quickly? ___________________YES NO

53. Can you imagine what it must be like to be very lonely? __________YES NO

54. Does it worry you when others are worrying and panicky? ________YES NO

Appendix B

Barratt Impulsivity Scale

BIS-11

Participant#_____________

Directions: People differ in the ways they act and think in different situations.

This is a test to measure some of the ways in which you act and think.

Read each statement carefully and **darken the appropriate circle** to the right of the statement.

Answer quickly and honestly.

	Rarely/Never	Occasionally	Often	Almost Always
1. I plan tasks carefully --	○	○	○	○
2. I do things without thinking ----------------------------------	○	○	○	○
3. I make up my mind quickly ----------------------------------	○	○	○	○
4. I am a happy-go-lucky --	○	○	○	○
5. I don't "pay attention" --	○	○	○	○
6. I have "racing" thoughts --------------------------------------	○	○	○	○
7. I plan trips well ahead of time ------------------------------	○	○	○	○
8. I am self-controlled --	○	○	○	○
9. I concentrate easily --	○	○	○	○
10. I save regularly --	○	○	○	○
11. I "squirm" at plays or lectures --------------------------------	○	○	○	○

12. I am a careful thinker -- ○ ○ ○ ○

13. I plan for job security -- ○ ○ ○ ○

14. I say things without thinking ---------------------------------- ○ ○ ○ ○

15. I like to think about complex problems --------------------- ○ ○ ○ ○

16. I change jobs -- ○ ○ ○ ○

17. I act “on impulse” -- ○ ○ ○ ○

18. I get easily bored when solving thought problems --------- ○ ○ ○ ○

19. I act on the spur of the moment ------------------------------- ○ ○ ○ ○

20. I am a steady thinker --- ○ ○ ○ ○

21. I change where I live --- ○ ○ ○ ○

22. I buy things on impulse -- ○ ○ ○ ○

23. I can only think about one problem at a time --------------- ○ ○ ○ ○

24. I change hobbies -- ○ ○ ○ ○

25. I spend or charge more than I earn --------------------------- ○ ○ ○ ○

26. I have outside thoughts when thinking ---------------------- ○ ○ ○ ○

27. I am more interested in the present than the future -------- ○ ○ ○ ○

28. I am restless at lectures or talks ------------------------------ ○ ○ ○ ○

29. I like puzzles -- ○ ○ ○ ○

30. I plan for the future --- ○ ○ ○ ○

<u>PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS</u>

Appendix C

Word List for Emotional Stroop task

Practice Words	Negative	Neutral	Positive
JARRED	PLAGUE	WINDOW	FRAGRANCE
BAT	VICTIM	COIL	TENDERNESS
VINE	CRASH	HALL	DESIRE
LASH	FAILURE	FORK	DATE
SNOUT	BURGLARY	WHISTLE	ECSTASY
CRUMBLE	ASSASSINATION	EFFECT	PARTY
CLAIM	ACCIDENT	OATS	HUMOUR
DRIVER	HUNGER	CLOCK	BIRTH
BEDROOM	THEFT	BANNER	TRIUMPH
CATS	STRIFE	PERSON	FUN
COLLAR	VIRUS	CUP	LOVE
CLAY	CRIME	SPOON	FLIRT
DISSECT	GRIEF	BRANCH	BABY
POTATO	LEAVE	POSTER	FUTURE
REAL	ULCER	FAN	HAPPINESS
	MURDER	SHOVEL	DANCE
	CORPSE	INFLUENCE	WEDDING
	DANGER	POLE	LINGERIE
	HOSTAGE	PRIEST	DARLING
	BLAME	HAMMER	FANTASY

Appendix D

ANOVA results for the Task Knowledge group

Table 12 Main effects and interactions for Pattern, Impulsivity and Task Knowledge

Multivariate Tests					
Effect	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pattern	8.06	1.000	169.000	.005	.046
Pattern X Impulsivity	2.14	2.000	169.000	.121	.025
Pattern X Task Knowledge	8.28	1.000	169.000	.005	.047
Pattern X Impulsivity X Task Knowledge	0.78	2.000	169.000	.461	.009

Tests of Between-Subjects Effects				
Source	Df	F	Sig.	Partial Eta Squared
Impulsivity	2	.355	.702	.004
Task Knowledge	1	3.122	.079	.018
Impulsivity X Task Knowledge	2	.342	.711	.004

Table 13 Results summary for Preference Formation of the Task Knowledge and No Task Knowledge groups analyzed separately

Multivariate Tests						
Task Knowledge	Effect	Value	F	df	Error df	Sig.
No	Pattern	.000	.003	1.000	150.000	.959
	Pattern X Impulsivity	.020	1.564	2.000	150.000	.213
Yes	Pattern	.423	13.921	1.000	19.000	.001
	Pattern X Impulsivity	.183	2.127	2.000	19.000	.147

Tests of Between-Subjects Effects				
Task Knowledge	Source	df	F	Sig.
No	Impulsivity	2	.357	.700
	Error	150		
Yes	Impulsivity	2	.440	.651
	Error	19		

Appendix E

ANOVA results for the 90% Recognition group

Table 14 Main effects and interactions for Pattern, Impulsivity and 90% Recognition

Multivariate Tests					
Effect	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pattern	6.34	1.000	169.000	.013	.036
Pattern X Impulsivity	2.18	2.000	169.000	.117	.025
Pattern X 90% Recognition	15.03	1.000	169.000	.000	.082
Pattern X Impulsivity X 90% Recognition	2.05	2.000	169.000	.133	.024

Tests of Between-Subjects Effects				
Source	df	F	Sig.	Partial Eta Squared
Impulsivity	2	.098	.907	.001
90% Recognition	1	.449	.503	.003
Impulsivity X 90% Recognition	2	.380	.684	.004

Table 15 Results summary for the Preference Formation of the 90% and No 90% Recognition groups analyzed separately.

Multivariate Tests					
90% Recognition	Effect	F	df	Error df	Sig.
No	Pattern	1.680	1.000	118.000	.197
	Pattern X Impulsivity	.201	2.000	118.000	.818
Yes	Pattern	14.943	1.000	51.000	.000
	Pattern X Impulsivity	3.394	2.000	51.000	.041

Tests of Between-Subjects Effects				
90% Recognition	Source	df	F	Sig.
No	Impulsivity	2	.744	.478
	Error	118		
Yes	Impulsivity	2	.093	.911
	Error	51		

Appendix F

ANOVA results for the 10% Recognition group

Table 16 Main effects and interactions for the 10% Pattern Recognition group and Impulsivity

Effect	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pattern	3.27	1	169	0.072	0.02
Pattern X Impulsivity	1.52	2	169	0.221	0.02
Pattern X 10% Recognition	4.73	1	169	0.031	0.03
Pattern X Impulsivity X 10% Recognition	0.04	2	169	0.965	0.00

Tests of Between-Subjects Effects

Source	df	F	Sig.	Partial Eta Squared
Impulsivity	2	.089	.915	.001
10% Recognition	1	5.909	.016	.034
Impulsivity X 10% Recognition	2	.517	.597	.006

Table 17 Results summary for the Preference formation of the 10% and No 10% Recognition groups analyzed separately

Multivariate Tests

10% Recognition	Effect	F	Hypothesis df	Error df	Sig.
No	Pattern	.135	1.000	126.000	.714
	Pattern X Impulsivity	1.691	2.000	126.000	.188
Yes	Pattern	4.945	1.000	43.000	.031
	Pattern X Impulsivity	.440	2.000	43.000	.647

Tests of Between-Subjects Effects

10% Recognition	Source	df	F	Sig.
No	Impulsivity	2	.324	.724
	Error	126		
Yes	Impulsivity	2	.287	.752
	Error	43		

Appendix G

Impulsivity and Explicit Knowledge of Experimental Conditions

Table 18 ANOVA results for Preference Formation scores of Impulsivity and Task Knowledge groups.

Tests of Between-Subjects Effects			
Source	Df	F	Sig.
Impulsivity	2	0.35	0.70
Task Knowledge	1	3.12	0.08
Impulsivity X Task Knowledge	2	0.34	0.71
Error	169		

Multivariate Tests				
Effect	F	Hypothesis df	Error df	Sig.
Pattern	8.06	1	169	0.01
Pattern X Impulsivity	2.14	2	169	0.12
Pattern X Task Knowledge	8.28	1	169	0.00
Pattern X Impulsivity X Task Knowledge	0.78	2	169	0.46

Table 19 ANOVA results for Preference Formation scores of Impulsivity and 90% Recognition groups.

Tests of Between-Subjects Effects			
Source	df	F	Sig.
Impulsivity	2	0.10	0.91
90% Recognition	1	0.45	0.50
Impulsivity X 90% Recogntion	2	0.38	0.68
Error	169		

Multivariate Tests				
Effect	F	Hypothesis df	Error df	Sig.
Pattern	6.34	1	169	0.01
Pattern X Impulsivity	2.18	2	169	0.12
Pattern X 90% Recognition	15.03	1	169	0.00
Pattern X Impulsivity X 90% Recognition	2.05	2	169	0.13

Table 20 ANOVA results for Preference Formation Scores of Impulsivity and 10% Recognition groups

Tests of Between-Subjects Effects			
Source	df	F	Sig.
Impulsivity	2	0.09	0.92
10% Recognition	1	5.91	0.02
Impulsivity X 10% Recognition	2	0.52	0.60
Error	169		

Multivariate Tests				
Effect	F	Hypothesis df	Error df	Sig.
Pattern	3.27	1	169	0.07
Pattern X Impulsivity	1.52	2	169	0.22
Pattern X 10% Recognition	4.73	1	169	0.03
Pattern X Impulsivity X 10% Recognition	0.04	2	169	0.97

Appendix H

BIS-11 subscales and Emotional Stroop task

A multivariate ANOVA was used to examine how the four difference BIS-11 subscales affected mean RT and Number of Errors made on the Emotional Stroop task. For the mean RTs, there was no overall effect of Word Category ($F(2,115) = .06$, $p = .94$). There was no effect of Attention on mean RT in the Emotional Stroop task, (Figure 12 A; $F(2,116) = .29$, $p = .75$) and no significant Attention X Word Category ($F(4,232) = 2.20$, $p = .07$) interaction. There was an effect of Motor Impulsivity on mean RT in the Emotional Stroop task, (Figure 12 B; $F(2,116) = 3.79$, $p < .05$). Pairwise comparisons revealed that there was a statistically significant difference between the medium and high Impulsivity groups ($p < .05$) and that the low and high groups were not significantly different ($p = .09$). Furthermore, there was no significant Motor X Word Category ($F(4,232) = .86$, $p = .49$) interaction. There was no significant effect of Self-Control on mean RT in the Emotional Stroop task, (Figure 12 C; $F(2,116) = 1.12$, $p = .33$). There no Self-Control X Word Category ($F(4,232) = 1.65$, $p = .16$) interaction. There was no effect of Cognitive Complexity on mean RT in the Emotional Stroop task, (Figure 12 D; $F(2,116) = .15$, $p =.86$) and no significant Cognitive X Word Category ($F(4,232) = .21$, $p = .93$) interaction.

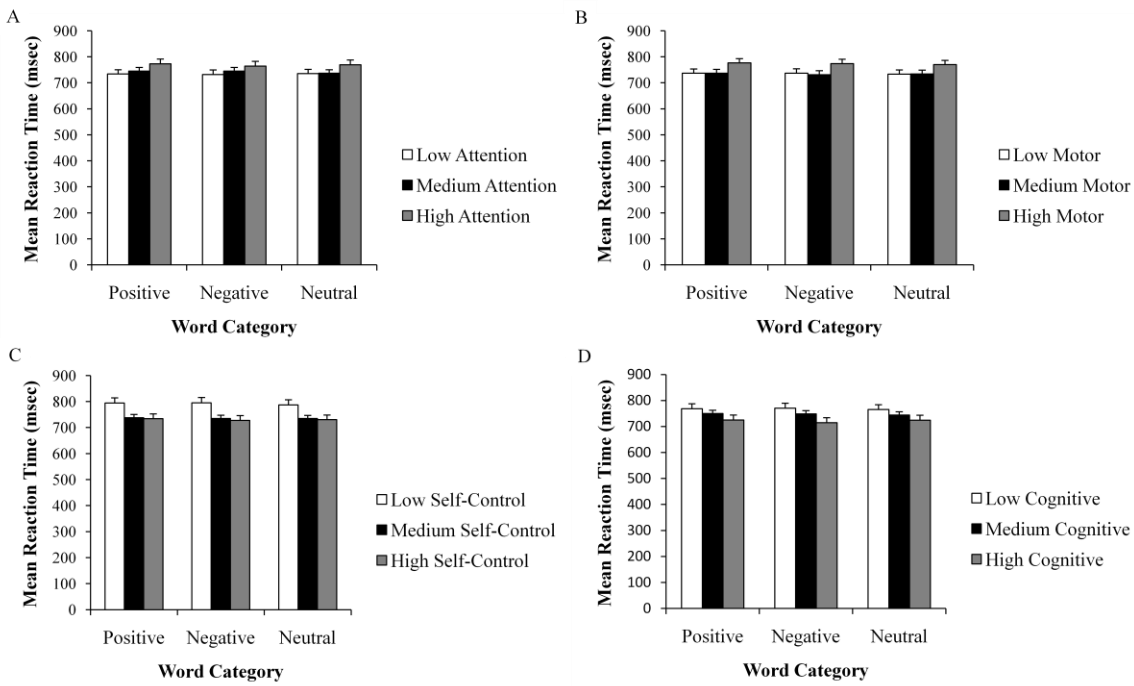

Figure 12 Relationship between the four BIS-11 subscales (A) Attention, B) Motor, C) Self-Control and D) Cognitive) and mean reaction time (msec) in response to the positive, negative and neutral words, in the Emotional Stroop task.

For the mean Number of Errors, there was an overall effect of Word Category ($F(2,115) = 89.02$, $p < 0.01$). There was no effect of Attention on the mean Number of Errors in the Emotional Stroop task (Figure 13 A; $F(2,116) = 0.90$, $p = .41$) and no significant Attention X Word Category interaction ($F(4,232) = 1.04$, $p = .39$). There was no effect of Motor Impulsivity on the mean Number of Errors in the Emotional Stroop task (Figure 13 B; $F(2,116) = 1.19$, p = .31) and no significant Motor X Word Category ($F(4,232) = .94$, $p = .44$) interaction. There was no effect of Self-Control on the mean

Number of Errors in the Emotional Stroop task (Figure 13 C; $F(2,116) = 1.80$, $p = .17$) and no significant Self-Control X Word Category ($F(4,232) = 1.61$, $p = .17$) interaction. There was no effect of Cognitive Complexity on the mean Number of Errors in the Emotional Stroop task (Figure 13 D; $F(2,116) = 0.55$, $p = .58$) and no significant Cognitive X Word Category ($F(4,232) = 1.20$, $p = .31$) interaction.

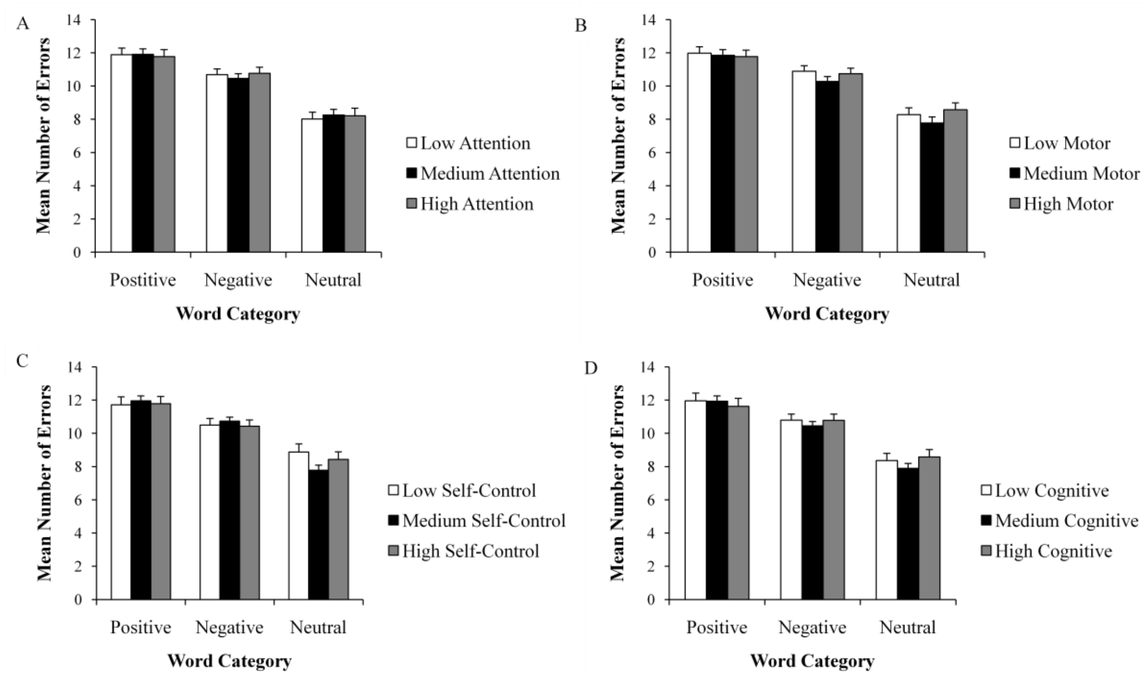

Figure 13 Relationship between the four BIS-11 subscales (i.e., A) Attention, B) Motor, C) Self-Control and D) Cognitive) and mean number of errors in responding to the positive, negative and neutral words on the Emotional Stroop task.

Appendix I

BIS-11 subscales and PRL

A 3 (Impulsivity) X 2 (Stage of Task) repeated-measures ANOVA was used to examine how the four different subscales (i.e., Attention, Motor, Self-Control and Cognitive) of the BIS-11 affected the errors to criterion as well as the mean number of errors for the Acquisition (i.e., learning errors) and Reversal (i.e., perseverative errors) stages of the PRL task.

There was no main effect of Attention on the mean number of errors to criterion for the Acquisition (i.e., learning errors) ($F(2,147) = .56$, $p = .57$) or Reversal (i.e., perseverative errors) stages of the PRL task ($F(2,154) = 1.73$, $p = .18$), as shown in Figure 14 A. There was no main effect of Motor Impulsivity on the mean number of learning ($F(2,147) = .60$, $p = .55$) or perseverative ($F(2,154) = 1.25$, $p = .29$) errors of the PRL task, as shown in Figure 14 B. There was also no main effect of Self-Control on the mean number of learning ($F(2,147) = .99$, $p = .38$) and perseverative ($F(2,154) = 1.19$, $p = .31$) errors of the PRL task, although this trended toward significance, as shown in Figure 14 C. Finally, there was no main effect of Cognitive Complexity on the mean number of learning ($F(2,147) = .88$, $p = .42$) or perseverative ($F(2,154) = .63$, $p = .53$) errors of the PRL task, as shown in Figure 14 D.

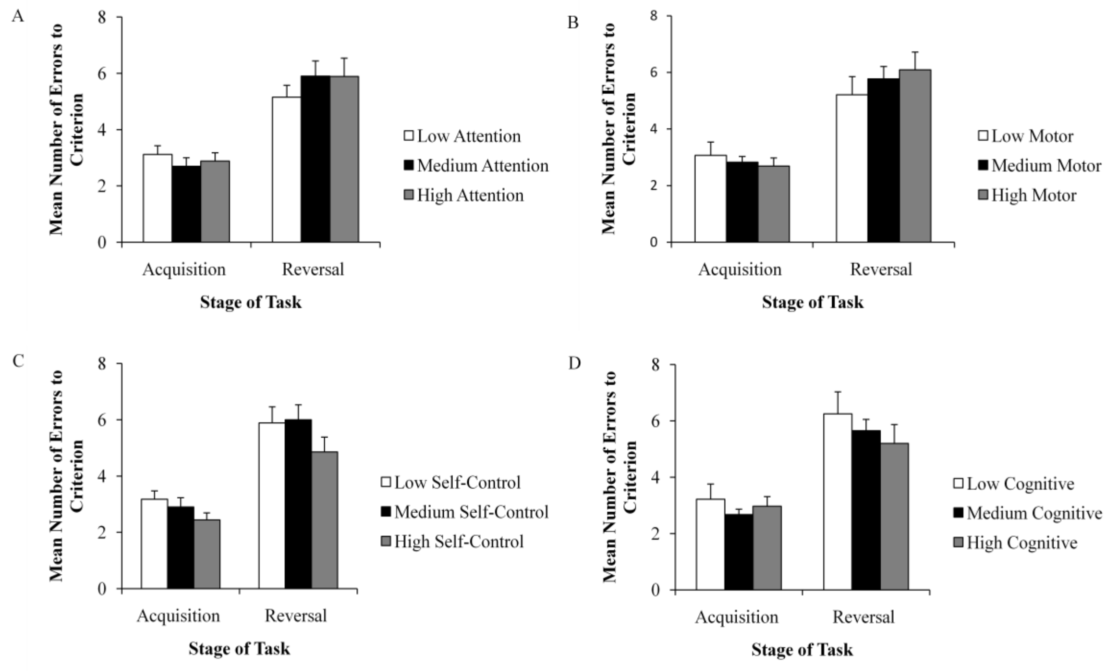

Figure 14 Relationship between the four subscales of the BIS-11 (i.e., A) Attention, B) Motor, C) Self-Control and D) Cognitive) and mean number of errors on the PRL task.

Mean number of total errors and errors to criterion at Acquisition and Reversal stages of the PRL task for participants scored as low, medium and high on each of the four subscales.

There was an effect of Attention on the mean number of errors in the Acquisition ($F(2,181) = 3.02$, $p = 0.05$) but not the Reversal ($F(2,181) = 1.05$, $p = .35$) stage of the PRL task, as shown in Figure 15 A. There was also no effect of Motor Impulsivity on the mean number of errors in the Acquisition ($F(2,181) = .30$, $p = .74$) and Reversal ($F(2,181) = .28$, $p = .76$) stages of the PRL task, as shown in Figure 15 B. Next, there was no effect of Self-Control on the mean number of errors in the Acquisition ($F(2,181) = .07$, $p = .93$) or Reversal ($F(2,181) = 1.06$, $p = .35$) stages of the PRL task, as shown in

Figure 15 C. Finally, there was no effect of Cognitive Complexity on the mean number of errors in the Acquisition and Reversal stages of the PRL task, as shown in Figure 15 D.

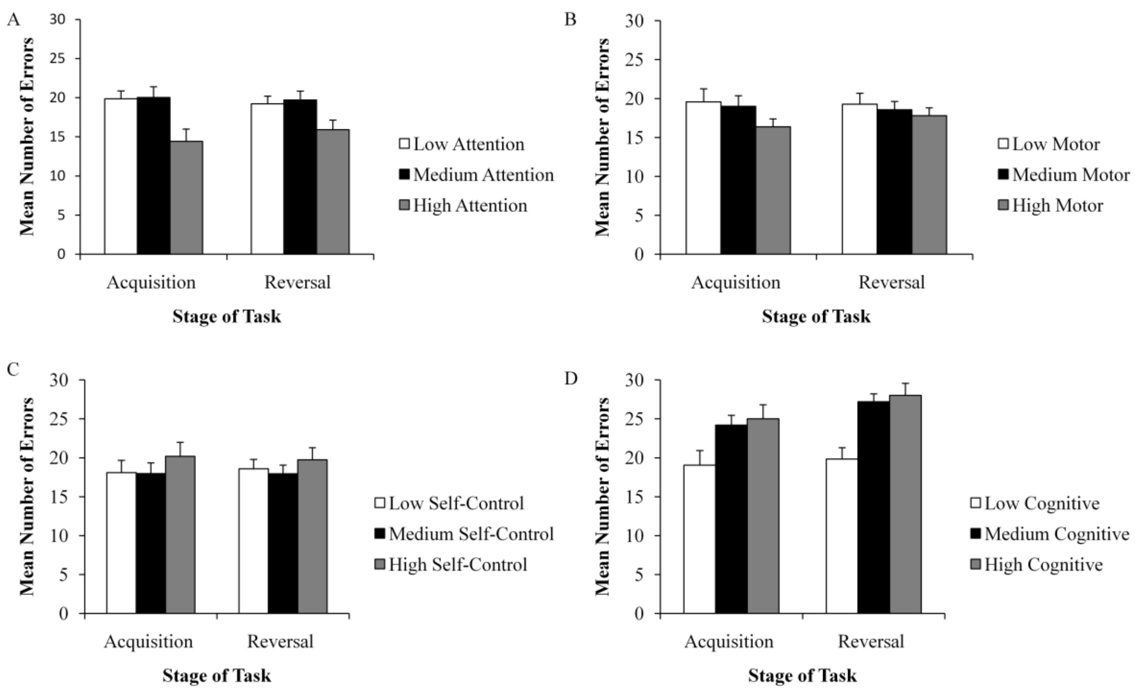

Figure 15 Relationship between the four subscales of the BIS-11 (A) Attention, B) Motor, C) Self-Control and D) Cognitive) and mean number of errors in the Acquisition and Reversal stages of the PRL task for participants scored as low, medium or high on each of the four subscales