Improving the Measurement of the Reinforcement Sensitivity Theory in Alcohol Misuse: Evidence from a New Laboratory Task

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ABSTRACT

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Matthew T. Keough

Gray's revised Reinforcement Sensitivity Theory (RST) posits that the behavioural inhibition system (BIS) resolves motivational conflict by allocating resources for approach (behavioural activation system [BAS]) or avoidance (Fight/Flight/Freeze System [FFFS]). Persons with a strong BIS over-attend to threat, leading to elevated anxiety and behavioural ambivalence. The role of elevated BIS in alcohol use is complex, as anxiety may promote self-medication drinking, while attention to threat may be a protective factor. Theory and recent data suggests that a concurrent strong BAS makes the anxiolytic effects of alcohol more salient, biasing BIS conflict towards drinking. Existing laboratory tasks do not measure BIS as a conflict system and therefore, examinations of the complex interplay between the BIS and BAS for understanding alcohol use are limited. This study tested a new laboratory task [Motivational Flanker Task (MFT)] that better reflects the revised BIS and FFFS and used this new measure to test BAS as a moderator of the BIS-alcohol misuse relation. Undergraduates (N=150) completed self-reports of BAS/BIS/FFFS, and alcohol misuse, and completed the MFT and the Point Scoring Reaction Time Task (PSRTT). Results indicated that MFT measurement of BIS motivational conflict was consistent with self-report and PSRTT measures. MFT measurement of BAS (reward responsivity), but not FFFS (punishment sensitivity) was consistent with self-report measures. An elevated BIS was linked to alcohol misuse, but only at high BAS. These results demonstrate that the MFT is a promising measure of the revised BIS. Further, considering the joint effects of BIS and BAS clarified risk for alcohol misuse.

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Dedication

I would like to dedicate my thesis to my wife, Katie. Thank you for keeping a level head in even the most stressful of times. Your love and dedication made it possible for me to succeed. I love you more than you could ever know.

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Introduction

Alcohol misuse is common among young Canadians. Alcohol misuse is defined as *heavy drinking* and experiencing *negative alcohol-related problems* (e.g., blacking out). An estimated one-third of undergraduates drink heavily (Adlaf, Demers, & Gliksman, 2004). While heavy drinking is linked to many negative health and psychological outcomes across the lifespan, it poses specific risks in university settings (O'Connor, & Stewart, 2010; Barnes, Welte, & Dintcheff, 1992). For example, more than 8% of Canadian students drive and/or have unplanned sex while intoxicated. Undergraduate drinking is a public health concern that warrants further empirical investigation.

Models of addiction posit that two reinforcement pathways are central to risk for alcohol misuse. Accordingly, some individuals drink alcohol to increase positive affect (e.g., to feel an elevated sense of "excitement") or more generally for positive reinforcement (Cooper, 1994; Martens & Martin, 2010). Conversely, other individuals are theorized to drink to alleviate aversive mood states (e.g., anxiety), thus drink for negative reinforcement purposes. Gray's Reinforcement Sensitivity Theory (RST; 1970; 1982; 1987) of personality attributes individual differences in motivation, as well as affect, and behaviour to the relative strength of three underlying neurobiological systems (Corr, 2004). Personality models that emphasize individual differences in motivation, like the RST, are particularly important for clarifying the reinforcement risk pathways to alcohol misuse. The three RST systems are the behavioural activation system (BAS), the behavioural inhibition system (BIS) and the Fight-Flight system (FFS). While rooted in animal learning data, the RST was adapted by social scientists to explicate the underlying personality differences relevant to the development and maintenance of substance use disorders (O'Connor & Colder, 2004; O'Connor & Colder, 2009; O'Connor, Stewart & Watt, 2009). Despite its widespread use and theoretical importance, the original RST was revised over a decade ago to account for new animal data on the neuropsychology of anxiety. These revisions have been slow to enter the literature, and it has been argued (Corr, 2008) that the new hypotheses of the revised RST need to be put to the empirical test because they have potential implications for understanding human behaviour.

The central purpose of the current study was to provide much needed empirical support for the revised RST in the context of alcohol misuse. The first step towards this goal was to develop theoretically sound measures of these revised systems. Currently, the author is unaware of such measures in the literature. In light of this, the present study drew on existing questionnaires as well as developed a new behavioural task in an effort to provide the necessary assessments. These new measures were then used to test major hypotheses stemming from the revised RST with respect to alcohol misuse.

The Original RST

The BAS was hypothesized to be a reward-sensitive system that mediates approach responses to appetitive or positively reinforcing stimuli (Corr, 2008). Thus, the BAS is activated in response to cues signalling potential reward. Activation of the BAS moves individuals towards appetitive goals, leading to increased self-reports of desire or wanting. This activation gives rise to positive affect and has been associated with the personality traits of extraversion (i.e., "outgoing" and "fun-seeking") and impulsivity

(Smillie, Pickering & Jackson, 2006). The neural substrate of the BAS was assumed to be located in “reward-sensitive” dopaminergic areas of the limbic system (Reuter, 2008). As such, the BAS theoretically maps onto the positive reinforcement pathway to alcohol misuse. Supporting this, Colder and O’Connor (2002) found that attentional biases towards rewarding cues were associated with high levels of alcohol use and drinking to increase positive mood.

In contrast, the BIS was conceptualized as a punishment-sensitive system, which subsumed control over sensitivity to aversive stimuli. Thus, the BIS is activated in response to punishment cues. Activation of the BIS leads to behavioural inhibition, and this inhibition gives rise to negative affect – primarily anxiety (Smillie, Pickering, & Jackson, 2006). The BIS was assumed to be located in the subiculum and septo-hippocampal structures of the brain (Corr, 2008). At the personality level, those with an elevated BIS are characterized by high anxiety, and experience intense ruminative thoughts (Windle, 1994). Given that BIS activation is believed to result in anxiety, the BIS was hypothesized to map onto the negative reinforcement pathway to addiction. Yet, empirical support for BIS as a risk factor in alcohol misuse is inconsistent (O’Connor & Colder, 2009; Colder, 2001). One potential reason for these mixed findings is that the relation between BIS and risk behaviour is complex. On the one hand, individuals with a high BIS may self-medicate their anxiety by drinking (e.g., anxiolytic effects of alcohol). On the other hand, a high BIS may be a protective factor, as hypersensitivity to punishment cues (e.g., alcohol induced hangover) may lead to avoidance of alcohol use.

Gray’s FFS was hypothesized to be sensitive to unconditioned aversive stimuli that signalled immediate threat or danger, giving rise to primal emotions of fear, panic and rage (Corr, 2008). Accordingly, the output of the FFS was either fight, if the threat was proximal and unavoidable (manifested in defensive aggression) or flight (manifested in rapid escape) if the threat was distal and could be easily avoided. The neural structure of the FFS was assumed to be complex and included several regions of the amygdala, the hippocampus, and the midbrain (Corr, 2004; Corr, 2008). Given that the FFS was thought to be reflexive of extreme fear or danger, it remains largely untested; and has not been conceptually linked to personality or behaviour (Corr, 2002). There are two potential explanations for this. First, because the BIS and FFS mediated responses to aversive stimuli, their independent contributions to behaviour, emotion, and personality were blurred (Smillie, Pickering, & Jackson, 2006). Second, many researchers theoretically equated fear (i.e., FFS output) with anxiety (i.e., BIS output) and this equivalence permeated the psychometric and laboratory assessment of the RST (Smillie, Pickering, & Jackson, 2006). Many authors have contended this equivalence (Gray & McNaughton, 2000; Corr, 2004; Smillie, Pickering & Jackson, 2006), and have called for the revision of experimental procedures to test individual differences in both fear and anxiety.

The Revised RST

In the revised RST, changes were made to each of the three motivational systems. The BAS remains relatively unchanged when compared to the other two RST systems. The BAS continues to function as a reward system. However, in contrast to Gray's original RST, the BAS is now posited to mediate approach responses to *all* appetitive stimuli, not simply conditioned cues of reward (Smillie, Pickering & Jackson, 2006; Corr, 2008). The dopaminergic limbic structures are still assumed to underlie BAS reactivity to reward.

The BIS is now conceptualized to be a motivational conflict resolution system in the brain (Corr, 2008), located neurally along the septo-hippocampal system and the amygdala (Gray & McNaughton, 2000; Wacker, Chavanon, Leue & Stemmler, 2010). In the revised RST, the BIS no longer mediates responses to punishment cues. Instead, the BIS functions to resolve conflict between competing motivational goals in the presence of simultaneous reward and punishment cues (e.g., BAS-approach and FFFS-avoidance conflict). In response to this competing information, the BIS inhibits ongoing behaviour and engages a risk assessment process that includes scanning the environment for threat-related information and scanning memory for internal threat-relevant information (Corr, 2002). This risk evaluative process results in high anxiety and occurs until an appropriate response is selected. Yet, perhaps due to evolutionary mechanisms, the BIS is presumed to favour avoidance responses (Smillie, Pickering & Jackson, 2006).

The FFS was renamed as the Fight, Flight and Freeze system (FFFS) to account for observations of fear responses in animals. The new FFFS is theorized to mediate responses to *all* aversive stimuli (both conditioned and unconditioned). The output of the FFFS is the "get me out of here" emotion of fear (Corr, 2008, pg. 10), not anxiety. Individuals with a strong FFFS should be biased in their attention to negative or potentially punishing stimuli. Increased FFFS activity manifests in such overt traits as fear-proneness and avoidance (Corr, 2008; DeYoung, 2010). The FFFS in the revised model lends itself to improved measurement and subsequent interpretation at both mechanism (e.g. negative attentional biases) and personality (e.g. traits) levels.

The revised RST offers a useful theoretical framework for understanding motivational individual differences in risk for alcohol misuse. The BAS is still posited to map onto the positive reinforcement pathway to appetitive risk behaviours, and has been shown across several studies to be a risk factor for alcohol misuse (Corr, 2004; Corr, 2002). The revised RST also implicates the BIS in appetitive risk behaviour; however, this relation remains complex (as in the original theory). Specifically, BIS activation gives rise to high levels of anxiety, which theoretically may lead to drinking to cope, thus supporting a negative reinforcement pathway. Alternatively, the BIS as a conflict resolution system may serve as a protective factor, as activation of the BIS leads to behavioural inhibition while drawing attention to threat. The result of this process should be behavioural avoidance

Extending beyond looking at these behavioural systems as unique correlates of risk behaviour, the *joint subsystems hypothesis* (Corr, 2002) suggests that there may be utility in looking at the interactive effects of these systems. In the original theory, these systems were assumed to be orthogonal, meaning that each system had its own independent influence on behaviour (Corr, 2008). But, the joint subsystems hypothesis predicts that the BIS moderates the influence of BAS on engagement in risk behaviours for positive reinforcement. Without a strong BIS drawing attention to threat, a high BAS should be associated with behavioural impulsivity, and drinking behaviour. In other words, individuals with a strong BAS and weak BIS are at most risk for behavioural disinhibition and substance use (O’Connor & Colder, 2009). A recent study by O’Connor and Colder (2009) supported this interaction - as participants with the high BAS, but low BIS combination more readily activated positive relative to negative cue-elicited alcohol attitudes on a priming task.

The joint subsystems hypothesis can be expanded to clarify the role of the BIS as a risk factor for drinking by considering BAS as a moderator. First, in order for anxious individuals (i.e., strong BIS) to engage in coping-motivated drinking, a concurrent strong BAS may be needed to make the tension-reducing effects of the behaviour more salient. This combination would resolve BIS conflict in favour of approach and drink to alleviate anxiety. Recent work suggests that BAS moderates BIS influence on drinking behaviour (Wardell, O'Connor, Read & O'Connor, 2011; Keough & O'Connor, 2011). For example, O'Connor, Stewert and Marlatt (2009) found that BIS was positively associated with cognitive expectancies for negative reinforcement but only for those high in impulsivity. Also, an elevated BIS has been linked to greater levels of prospective weekly alcohol use and alcohol-related problems in individuals with a concurrent strong BAS (Wardell, O'Connor, Read & O'Connor). This data provides promising support for the joint subsystems hypothesis; however, more empirical work is needed to replicate and expand on the nature of the BIS by BAS interaction in predicting drinking outcomes.

Problems in Revised RST Measurement

Questionnaire measures. Existing measures of the RST were designed to test the BAS and BIS under Gray's original RST, and therefore, refinement of these measures is needed to test the implications of the revised theory. There are two major scales widely used to capture individual differences in reward and punishment sensitivities: the Carver and White (1994) BIS/BAS Scales and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Ávila, Moltó, & Caseras , 2001). In the intended form, the use of both questionnaires is limited. However, current re-examinations of the Carver and White BIS/BAS Scales suggest that this measure reflects distinct BAS, BIS and FFFS constructs as defined by the revised RST. In this respect, several studies have been successful in showing that the BIS subscale of the Carver and White measure splits into two separate factors: one related to BIS-anxiety and the other related to FFFS-fear (Johnson, Turnen, Iwata, 2003; Heym, Ferguson and Lawrence, 2008; Polythress et al., 2009; Beck et al., 2009). Comparatively, studies on the SPSRQ have not been successful in finding a new factor structure that fits with the revised RST (Cogswell, Alloy, van Dullmen, and Fresco, 2006; O'Connor, Colder, and Hawk, 2004).

In light of these findings, the present study used the BIS/BAS Scales as the primary self-report measure of the revised RST systems. This choice was based on several findings showing that this scale captures all three motivational systems under the revised RST (Johnson, Turnen, Iwata, 2003; Heym, Ferguson and Lawrence, 2008; Beck et al., 2009; Polythress et al., 2009). A confirmatory factor analyses (CFA) was conducted on this scale to replicate and clarify the factor structure observed in previous studies. Specifically, it should be noted that there is a slight inconsistency in the literature regarding the status of one particular item ("If I think something unpleasant is going to happen I usually get pretty "worked up"). Some authors have noted that this item loads positively and strongly onto a BIS factor (Johnson, Turnen, Iwata, 2003; Polythress et al., 2009), whereas other researchers argue that this item captures sensitivity to punishment, and therefore, reflects FFFS under the revised RST (Corr, 2008; Heym, Ferguson and Lawrence, 2008; Beck et al., 2009). According to theory, this item should tap the FFFS; and hence, in the present study, this item was specified to load on a FFFS factor. Also, the BIS/BAS Scales were designed to measure three core facets of BAS, namely constructs referred to as Drive (persistent pursuit towards desired goals), Fun-Seeking (willingness to engage in potentially rewarding activities impulsively) and Reward Responsivity (positive responses towards reward opportunities) (Carver and White, 1994). Since the scale's development, many researchers have found support for these three core BAS factors (e.g., Jorm et al., 1998). Consequently, the author of the present study ran a CFA specifying a five-factor structure, with three factors reflecting BAS, and two factors representing BIS and FFFS, respectively. Once clarified, the factors can be applied to see how the revised systems predict alcohol misuse behaviour.

Laboratory measures. Several different cognitive conflict tasks have been used to measure the systems of the revised RST. The major limitation of these tasks is that they do not capture the revised BIS as a motivational conflict system. In addition to this, existing laboratory measures do not provide assessments of the FFFS. For example, recent studies have employed a classic Go/No-Go Task to measure the revised BIS (Amodio, Master, Lee & Taylor, 2008; De Pascalis,Varriale & D'Antuono, 2010; Wacker et al., 2010). In a standard Go/No-Go task, participants are asked to press a key (Go) when they see a certain stimulus on the screen (e.g. a letter "W") and withhold a response (No-Go) when they see another stimulus (e.g. a letter "M"). In most studies, approximately 80% of trials are Go responses, and the remaining 20% are No-Go trials, thus making inhibition of the Go response difficult.

Although the authors of these studies argue in favour of using a Go/No-Go paradigm to measure the revised BIS, the task is not necessarily appropriate to capture BIS conflict. Activation of the BIS results from goal-oriented conflict and not simply the presence of stimuli signalling general conflict (e.g., perceptual or response conflict). With this in mind, in the Go/No-Go Task, the conflict occurs at the response level and there are no reward-punishment contingencies underlying participants' responses. Correct Go responses do not result in a gain for participants, and hence are not reinforcing. Conversely, errors on No-Go trials are not punished. More accurately, the Go/No-Go Task measures impulsivity, as a greater number of errors on No-Go trials are hypothesized to reflect disinhibition.

Another laboratory task, called the Point Scoring Reaction Time Task (PSRTT; Avila, 2001, Colder & O'Connor, 2004), was designed to test the revised RST in children. During the task, children were asked to discriminate between odd and even numbers beneath coloured circles. In the first block, children were instructed to ignore circle stimuli and that correct responses would not yield an increase in points (no reward block). Responses in the second block differed from the first block only in that correct responses were rewarded, such that faster correct responses led to higher gains in points. For the third block (punishment block), participants were told that responses during green circle trials, whether correct or incorrect, would lead to a loss of 50% of accumulated points. Finally, during the last block (post punishment), the participants were told to respond normally for reward and that green circle trials would no longer result in a loss of points. As expected, children with a strong BAS showed the fastest reaction times to reward versus non-reward trials. This result is consistent with previous literature, as responses to *pure* reward have been shown to be valid indicators of BAS sensitivity (see Corr, 2008; Colder & O'Connor, 2002). Second, children's reaction times increased for reward cues that were previously associated with punishment (i.e., green circle trials moving from the punishment to post punishment block). The authors argued that this finding reflected BIS activation, as green circle trials evoked goal level conflict.

However, the present author argues that there are methodological issues in the PSRTT that limit this interpretation. Specifically, green circle trials are initially associated with heavy punishment (i.e., losing 50% of accumulated points). When these cues become associated with reward, it may be that individuals who are sensitive to punishment may still be overly cautious to respond, resulting in slower reaction times. This slow down may not be due to conflict detection, but due to hyper vigilance to punishment cues. Overall, the potential punishment associated with green circle trials may be more salient than reward, and according to theory, this would not give rise to BIS activation. According to Corr (2008), equal activation of reward (BAS) and punishment systems (FFFS) are needed to sufficiently activate BIS.

As discussed above, existing laboratory tasks of the revised RST have several limitations. The various cognitive tasks that have been employed to measure the revised BIS are insufficient to evoke goal level or motivational conflict, and these tasks also neglect FFFS measurement. Overall, a parsimonious laboratory task of the revised RST is needed – one that captures individual differences across all three motivational systems. To this end, such a task would have to extract responses to pure reward (BAS) and pure punishment (FFFS), and then sufficiently bring these contingencies together in conflict to derive a theoretically accurate measurement of the BIS.

The Present Study

Currently, the limitations of psychometric and laboratory assessments of the revised RST greatly limit the theory's applicability to alcohol misuse risk models. The primary goal of the present study was to validate a novel and improved laboratory measure of the revised RST, called the Motivational Flanker Task (MFT). The MFT was validated against the self-report measure of the revised RST and the BIS/BAS trial types of the PSRTT. With regard to the self-report measures, a CFA was conducted on the BIS/BAS Scales to test a factor structure that is consistent with the revised theory. The second major goal of this study was to use the MFT and self-report measures to investigate the BIS by BAS interaction in predicting drinking outcomes.

Broadly defined, the MFT is based on the classic Eriksen Flanker paradigm (Eriksen & Schultz, 1979; Ochsner et al., 2006). During a standard flanker task, participants are instructed to respond to target stimuli (commonly symbols, letters, or words) that are surrounded by distracters. Across trials, the distracters are either congruent (e.g., SSSSS) or incongruent with the target (e.g., SSHSS). Participants are told *only* to focus and respond to the middle target, and not the surrounding distracters or flankers. The purpose of the incongruent distracters is to create cognitive conflict, resulting in slower reaction times and more errors for targets during incongruent trials. In a recent experiment, Boksem and colleagues (2008) used a motivational adaptation of the standard flanker task where they randomly assigned participants into two groups. In the reward condition, participants were rewarded monetarily for correct responses and were not punished for incorrect responses. This block type was expected to measure BAS sensitivity. In the punishment condition, participants started out with a small amount of money and were punished monetarily for each incorrect response. This block type was hypothesized to capture BIS sensitivity. A primary limitation of this study is that they used a between groups design, where participants were *only* exposed to rewarding or punishing trials and not both. This means that participants did not have to make responses towards stimuli that induce motivationally-relevant conflict.

The major strength of the flanker paradigm is the ability to present conflicting stimuli *simultaneously* to participants and ask them to make speeded responses. Adding conflicting motivational contingencies to these stimuli would; therefore, enhance the measurement of the revised BIS. This is precisely the rationale behind the MFT. The MFT is based on an affective flanker paradigm, where emotional words (i.e., positive and negative) are presented as distracters above and below target words to induce conflict. The valence of the distracters is either congruent or incongruent with the valence of the target word. However, what is unique about the MFT is that it attaches reward and punishment components to positive and negative words, respectively. At the beginning of the task, participants started out with a set point value. Only correct responses to positive target words were rewarded with a large gain in points, whereas only incorrect responses to negative target words were punished with a large cost in points. As such, positive words signalled "reward", whereas negative words represented "punishment".

Hypotheses. It was hypothesized that reaction times on the MFT positive congruent trials (i.e., trials that signal only reward opportunity), versus control trials, would reflect BAS strength, such that those with a high, compared to low BAS, would have relatively faster reaction times. Conversely, reaction times on negative congruent trials (i.e., trials that represent only potential punishment), versus control trials, were hypothesized to reflect FFFS strength, such that those with a high, compared to low FFFS, would have relatively faster reaction times. It was also hypothesized that BIS strength would be tapped by performance on the incongruent trials that include positive targets and negative flankers. On these incongruent trials those participants who show relatively slower reaction times (versus control trials) would have a comparatively high

BIS. More explicitly, when approaching a positive target signalling reward, those high in BIS should be momentarily inhibited due to the negative flankers serving as punishment cues. The hypothesized assessments of the BAS, BIS, and FFFS stemming from the MFT were validated by examining correlates of reaction times in the aforementioned trials with self-report measures and performance on the PSRTT.

A CFA was conducted on Carver and White's (1994) BIS/BAS Scales. Recently, studies have found a factor structure that maps on to the revised RST – that is, several studies have identified three distinct BAS factors, a BIS factor and a FFFS factor (Johnson, Turnen, Iwata, 2003; Heym, Ferguson and Lawrence, 2008; Polythress et al., 2009; Beck et al., 2009). Before using the relatively new revised interpretation of the BIS/BAS Scales, the present study specified a CFA model based on the results of Heym et al., (2008), given that these authors tested a theoretically informed factor structure (Corr, 2008). Thus, it was expected that the CFA in the present study would replicate this five factor structure. These factors were hypothesized to relate to their corresponding trial types on the MFT. In terms of the PSRTT performance, reward trials on the PSRTT were expected to be statistically associated with positive congruent trials on the MFT, whereas green circle or conflict trials on the PSRTT would be strongly related to incongruent BIS trials on the MFT.

Lastly, for concurrent validity, the measures of BAS, and BIS were applied to alcohol misuse outcome behaviours. In accordance to the joint subsystems hypothesis (Corr, 2002), it was expected that the relation between BIS and alcohol misuse would be complex. The BAS was hypothesized to moderate this relation, such that those with concurrent high BIS and high BAS would be at greater risk for alcohol misuse, as indicated by higher weekly alcohol consumption and more alcohol-related problems.

Method

Participants

A sample of 150 undergraduate students (31 males, 119 females) was recruited from Concordia University. The majority of participants were White (74%), and the minority cultures represented in the sample were Canadian African (2.6%), Aboriginal (.7%), Canadian Asian (4%), Hispanic (2.6%), and “other” (16.1%). Of the total sample, 63% reported English and 18% reported French to be their dominant language, and 19% reported “other”. The majority of undergraduates reported living at home with their parents (72%), while 2.6% reported living on campus and 25.4% reported living off-campus.

Participants were recruited through Concordia’s online psychology participant pool, as well as through flyers posted on campus and in the community (e.g., coffee shops close to the university). As compensation for their participation, students received either course credit or $15. To be included in the study, students had to be between the ages of 18-25 years old. This provided a relatively homogeneous sample in terms of undergraduate trajectory, while also providing a sample that was of legal drinking age in the province of Quebec.

Laboratory Measures

Point Scoring Reaction Time Task (PSRTT; Avila, 2001; Colder & O’Connor, 2004). The PSRTT is a computerized cognitive task developed to measure the revised RST in children. The current study aimed to test the applicability of this task with a young adult (i.e., university students) sample. During the PSRTT, a cue shifts from being associated with punishment to being associated with reward. There are four experimental blocks, each composed of 50 3-second trials presented in a fixed order (*no reward, reward, punishment and post-punishment*). Across all blocks, the stimuli are the same and include a coloured circle above odd and even two digit numbers. Participants were instructed to discriminate between odd and even numbers using a key-press. Specifically, odd numbers were responded to with the '1' key and even numbers were responded to with the '2' key.

During the no reward block, correct responses were not associated with point gains; however, incorrect responses yielded a loss of 2-points (this loss value was constant across all blocks). In the reward block, correct responses yielded a variable reward that was contingent on reaction times (points = 835/RT in milliseconds). For both no reward and reward trials, participants were told to ignore the coloured circles and to respond only to the target numbers. Decreases in reaction times for reward trials (compared to no reward trials) were hypothesized to reflect BAS sensitivity. Before the punishment block, participants were told that making any response (correct or incorrect) when a green circle is present would result in a loss of 50% of their accumulated points. Otherwise, the instructions remained the same. Finally, before the post-punishment block, participants were told that the green circle would not cause a loss of points, and that they should respond to the targets in order to gain points. Slowed reaction times during green circle trials in the post-punishment block were hypothesized to reflect BIS sensitivity, as green circle trials – once associated with punishment – now signaled reward. In other words, green circle trials create motivational conflict by simultaneously activating the BAS and FFFS, which in turn activates the BIS and inhibits behaviour.

Motivational Flanker Task (MFT). The MFT for the current study was adapted from a commonly used affective flanker paradigm, where participants are required to make discriminative judgments about positive and negative target words using two different key-presses (Ochsner et al., 2006). This task was administered via a computer. During the MFT, positive and negative target words were presented with distracter words above and below, and neutral words were used to provide a baseline. There are two general types of trials: congruent (where the valence of the distracter words matched the target word) and incongruent (where the valence of the distracter words was opposite of the target word). In the MFT, there were two critical congruent trial types where all positive or all negative words were presented (see Appendix A, Panel A). Each of these trial types was compared against neutral congruent baseline trials. Also, there were two incongruent trial types (see Appendix A, Panels B and C). Again, each incongruent trial type had a corresponding control condition where positive and negative targets are surrounded by neutral flankers. Single targets were also equally intermixed with flanker trials to get baseline measures of overall response speed. Also, after each stimulus was presented a masking stimulus appeared in order to reduce potential priming effects (see Figure 1 for a schematic representation of a trial). Overall, there were 50 trials per trial type on the MFT.

In order for a word to be selected as a target, the words were matched at the category level (positive, negative, neutral category) on number of syllables, word length, and subtitle frequency (see Appendix B). A series of one-way ANOVAs revealed no statistically significant differences between the word categories on length (F = .037, p = .963), number of syllables (F = .439, p = .616), or subtitle frequency[1] (F = .033, p = .968). Subtitle frequency indicates how often, on average, a given word appears in North American film subtitles. This measure has been shown to account for a higher proportion of variance in lexical decision tasks than existing spoken or written word frequency indices (New, Brysbaert, Veronis, & Pallier, 2007). Also, effect size measures did not reveal any appreciable group differences on length, number of syllables, and subtitle frequency (see Table 1). Valence ratings for the words in the MFT were collected from participants at the end of the study. The response scale used to rate word valence ranged in value from 1 (extremely negative) to 9 (extremely positive). Neutral valence was denoted by responses that fall relatively in the middle of these extremes (i.e., values between 4 and 6). Valence was inspected at the item level.

Given that the revised RST systems are activated by motivational goals, the MFT attached reward and punishment qualities to the words. Before beginning the MFT, participants were informed that they have 250 points and that they should try their best to win as many points as possible by the end of the experiment. The experimenter stressed to the participant that a response should only be made to middle target words, and that they should ignore surrounding distracter words. They also were informed that in some cases they will see single words, and should respond to these accordingly. Participants were instructed to respond with the number '1' key for positive targets, the number '2' key for neutral targets, and the number '3' key for negative targets. Participants were informed that correct responses to the positive judgments only result in a gain (i.e.,

[1] Subtitle frequency estimates were obtained from (http://elexicon.wustl.edu/)

reward) of 50 points, while incorrect negative judgments only result in a loss (i.e., punishment) of 50 points. Correct responses to negative and incorrect responses to positive targets were not rewarded nor punished. For neutral trials, correct responses led to a gain of 5 points and an incorrect response cost the participant 5 points. The relative gain/cost of positive and negative responses was held constant across critical trials because measurement of goal conflict (i.e. BIS) requires equal activation of the BAS and the FFFS (Corr, personal communication, 2011). All stimuli were presented for 1500 milliseconds (ms).

For clarity, the MFT trial types will now be explicitly linked to the systems of the revised RST. First, reaction times for positive congruent trials versus neutral baseline trials were the primary measure of BAS sensitivity. The positive congruent trials signal pure reward for participants, and this method of assessing BAS is consistent with the revised RST literature (Corr, 2008). Second, participants' reaction times for negative congruent trials compared to baseline were used as the dependent measure of the FFFS. During these trials, the negative words signal opportunities for punishment only (i.e., a loss of 50 points), and therefore, should reflect FFFS activation. Third, reaction times on incongruent trials with positive targets and negative flankers were used as the dependent measures of the BIS. Accordingly, when responding to a positive target (signaling reward) that is flanked by negative words (signaling punishment), individuals who are high on BIS should be momentarily inhibited due to the presence of conflicting motivational input. No apriori hypotheses were expected for incongruent trials where negative targets are flanked by positive words.

Self-Report Measures

BIS/BAS Scales (Carver & White, 1994). The BIS/BAS Scales were initially constructed using the original RST. The BIS/BAS Scales consist of 20 self-report items. The BAS items were created to capture one's responsiveness to reward (e.g. "When I want something I usually go all-out to get it"); whereas the BIS items reflected one's sensitivity to punishment (e.g. "Criticism or scolding hurts me quite a bit"). Participants' responses are measured on a response scale, ranging from 1 (strongly agree) to 4 (strongly disagree). The questionnaire is broken down into four subscales: three measuring BAS strength (Reward Responsiveness [5 items], Drive [4 items], and Fun Seeking [4 items]) and the remaining one measuring BIS strength (7 items). The original scoring method involves taking composite subscale means for the BIS and the BAS.

Instead, in the current study, five subscales were derived from this measure, so that in addition to the original BAS subscales BIS and FFFS subscales were derived. These subscales are based on the previous work of Heym et al., (2008), where these authors identified a five factor structure that was consistent with the revised RST. Given that this is a relatively new way of conceptualizing these scales, the present author ran a CFA to confirm the item loadings suggested by Heym et al.'s work before using these scales in further analyses. Consequently, five subscale composite means (BAS-Drive, BAS Fun Seeking, BAS Reward Responsivity, BIS and FFFS) were calculated based on the final CFA-specified model. That is, the retained indicators for each factor were used to create composite subscale means and these were used in subsequent analyses. For use of the BIS/BAS Scales in its original format, Carver and White (1994) reported internal consistency coefficients that ranged from $\alpha = .66$ to .74 across the four subscales. Also, the authors noted test-retest reliabilities for the subscales over an eight week period that ranged from r = .59-.69.

In the current sample, the internal consistencies for the five self-report subscales were as follows: BAS Drive (α = .81), BAS Fun-Seeking (α = .70), BAS Reward Responsivity (α = .66), BIS (α = .70), and FFFS (α = .65). It should be noted that the final subscales obtained in the present study were slightly different from previous work on this scale (see Results). Also, the author acknowledges that internal consistencies of less than .70 are undesirable; however, these values could reflect a small indicator-to-factor correspondence. This is especially possible for item level data. Despite this limitation, all five subscales were used in subsequent analyses.

Young Adult Alcohol Consequences Questionnaire (Read, Kahler, Strong & Colder, 2006). In the present study, the YAACQ served as the primary measure of negative consequences associated with drinking in undergraduates. The YAACQ is a 48-item self-report questionnaire designed to be a multi-dimensional measure of alcohol problem severity. The items on the YAACQ quantify a variety of negative consequences related to alcohol use in the past year. The items span across several life domains, including social, occupational, physical, and impulsive control-related consequences. Responses to the items are either “yes” or “no”, which are coded as 1 and 0, respectively. Responses were summed to provide a total score. Relatively higher scores indicate a larger number of negative consequences experienced as a result of alcohol use. In the original article, the authors found support for an eight factor structure (social-interpersonal consequences, impaired control, self-perception, self-care, risk behaviours, academic/occupational consequences, physical dependence and blackout drinking) and the internal reliabilities ranged from α = .70-.91. Also, the YAACQ total score has been shown to be a reliable index of alcohol-related problems (α = .89) (Read, Lau-Barraco, Dunn & Borsari, 2009). Given that there are no a priori hypotheses regarding the role of the BAS, BIS, and FFFS (as theorized by the revised RST) for risk of specific alcohol negative consequences, the total YAACQ score was of primary interest. In the present sample, the reliability of the YAACQ total score was excellent (α = .93).

Alcohol consumption (Cahalan, Cisin, & Crossley, 1969; Read & O'Connor, 2006). To measure alcohol consumption, typical weekly frequency and quantity of alcohol use were assessed for the past month. Specifically, the frequency question asked, "In the past 30 days (1 month), on *average* how often did you have some kind of beverage containing alcohol?" Participants responded on a 7-point response scale ranging from "not at all in the past 30 days" to "everyday of the week". The quantity question asked, "How many drinks did you *usually* have on any one occasion in the past 30 days (1 month)?" Response options ranged from "did not drink at all in the past 30 days" to "ten drinks per occasion". The quantity and frequency variables were multiplied to yield a past-month quantity-frequency composite of alcohol use. The quantity by frequency product is a standard measure used in the alcohol literature (e.g., Wardell, O'Connor, Read & Colder, 2011).

Procedure

Upon arrival to the lab, participants completed demographic information as well as all of the self-report questionnaires described above. After the questionnaires were finished, participants completed the two reaction time tasks. The order of the MFT and PSRTT were counterbalanced across participants. If needed, a 10-minute break was given to participants between the reaction time tasks. Before each task, participants were informed that the top 5% of all scores at the end of the study would be entered into a draw for a cash prize of $50. The purpose of the draws was to increase participants' motivation to get as many points as possible during the tasks. A separate draw was conducted for the MFT and the PSRTT. Upon study completion, all participants were fully debriefed about the nature of the study.

Results

Data Analytic Overview

The analyses for the current study proceeded in three main stages. First, a five-factor CFA was specified based on previous studies (Heym, Ferguson and Lawrence, 2008; Beck et al., 2009). The CFA was conducted in Mplus version 2.12 (Muthen & Muthen, 2002). Given that the factors were derived from item level data that used four-point response scales, a Weighted Least Squares (WLS) estimation method was used. Item level factor analysis is problematic because the estimated correlations between categorical observed variables are typically lower than the correlations for underlying continuous latent variables (O'Connor, Colder, & Hawk, 2004). As Bryne (2001) notes, attenuated parameter estimates occur greatly when there are fewer than five categories per variable, as is the case in the current data (four response categories per item). The WLS estimation method adjusts the covariance matrix as if the variables were continuous.

As recommended by Kline (1998), model fit should not be evaluated on the basis of a single fit statistic. As such, overall model fit was assessed using several indices, including the Root Mean Error of Approximation (RMSEA; Steiger, 1990), the

Comparative Fit Index (CFI; Bentler, 1990) and the Tucker-Lewis Index (TLI; Tucker & Lewis, 1973) fit statistics. Although there are no set criteria for evaluating these fit statistics, Hu and Bentler (1999) recommend a cut-off of .06 or lower for the RMSEA, .95 or higher for the CFI, and .96 or higher for the TLI. Models that satisfy these criteria are considered to have excellent fit to the data (Longley, 2005). Others have proposed less stringent standards for these fit indices (RMSEA $\leq$ .10 and CFI $\geq$ .90; Weston & Gore, 2006).

Further, the criteria used in this study to distinguish substantial versus non-substantial factor loadings are based on the recommendations provided by Comrey and Lee (1992). These authors suggest that loadings greater than .70 should be considered excellent, .63 are very good, .55 are good, .45 are fair, and .32 are poor. In the present study, items with factor loadings less than .50 were dropped from the model, and hence, were not interpreted. Once identified, composite means on the subscales were used to validate the MFT and were also used to test hypotheses related to alcohol misuse outcomes.

Second, a series of hierarchical regression models were conducted to provide construct validity for the MFT trial types. For all trial types in both reaction time tasks, median scores were derived for each participant. Generally, in these models, reaction times for each critical trial type on the MFT were entered as criterion variables. The relevant control trial reaction times were entered in the first block as covariates, followed by the five self-report subscales and the corresponding PSRTT trials as predictors in the second block. For the PSRTT, unstandardized residual scores were computed to provide single measurements of BIS and BAS strength as measured by this task. PSRTT reward residuals (BAS) were created by specifying *reward block* reaction times as the criterion with *no-reward block* (control) reaction times as a predictor. These residual scores were saved into the data file. PSRTT conflict residuals (BIS) were created by specifying reaction times for *green circle trials* in the post-punishment block as the criterion and median reaction times for *non-green circle trials* (control) were entered as a predictor. The purpose of creating these residual values was to extract meaningful scores related to reward and conflict sensitivities, once variance related to control trials was partialled out.

Third, a series of hierarchical moderated regression analyses were used to test hypotheses related to the BIS by BAS interactions in predicting weekly alcohol consumption and alcohol-related problems. The first two moderation models of interest were using MFT measurements of BIS and BAS to predict alcohol outcomes. As argued earlier, the author believes that the MFT has the potential to clarify the RST in alcohol misuse. To this end, BAS and BIS unstandardized residual scores were created using the MFT. These residual scores were then entered in the first block, followed the interaction term to predict alcohol-related problems and alcohol consumption in separate models. To explore the BIS by BAS interaction further, subsequent moderation analyses were conducted using BIS residuals from the MFT and the three BAS self-report subscales as moderators. Given that the BAS is theoretically multi-faceted, the purpose of these models was to investigate how different aspects of BAS may moderate the BIS-alcohol misuse relation. Regardless of statistical significance, simple slopes and effect sizes were reported and interpreted. The simple slopes for BIS predicting drinking outcomes were examined at high (1SD above the mean) and low (1SD below the mean) BAS. All predictor variables were centered prior to creating interaction terms and running the moderated regression models.

The effect sizes for simple slopes were calculated using the following formula:

$$f^2 = \frac{\text{semi-partial correlation}^2}{1-R^2}$$

where the numerator refers to the systematic variance explained by an effect relative to the unexplained variance in the criterion variable (Aiken & West, 1991) . Cohen (1988) suggests guidelines for interpreting the magnitude of simple slope effect sizes (small: f^2 = .02, medium: f^2 = .15, large: f^2 = .35). It should be noted that these guidelines are not meant to be applied stringently to effect size interpretations. More precisely, Cohen's qualitative effect size magnitude categories are meant to be used in conjunction with an investigator's knowledge of the research area (i.e. what constitutes an appreciable versus non-appreciable effect size in a given domain of research).

Data Screening

Before conducting any analyses, the data were screened according to the recommended best practices outlined by Wilkinson (1999) and Kline (2009). All continuous variables were standardized in order to detect the presence of extreme scores or outliers. A z-score of greater than 3 was used to determine the status of extreme scores (Kline, 2009). The statistical assumptions of multiple regression were verified, including multivariate normality, linearity, homoscedasticity, and the absence of perfect multicollinearity.

For the questionnaire data, there were no missing cases. Also, standardized scores on these self-report variables did not reveal the presence of any outliers. For the MFT, median reaction times were calculated for each trial type. Medians were based on correct responses only, and incorrect trials were deleted from the data set (3.8% overall). Additionally, reaction times greater than ±3 SDs were replaced with the highest acceptable median value within the specified range. Lastly, reaction times less than 250 ms were deleted from the data set (.58%) because these likely reflect anticipatory responses before participants had a chance to process the stimuli (Arguin et al., 2000). For the PSRTT, outliers were handled in the same manner as for the MFT. A total of 2% of trials were excluded due to errors and less than 1% of trials fell below 250 ms.

All continuous predictor and criterion variables were inspected graphically and numerically to ensure that each variable was normally distributed. According to Kline (2009), variables with a skew less than 3 and a kurtosis less than 10 are considered to be normally distributed. In the current sample, all variables showed acceptable skew and kurtosis; therefore, no transformations were applied.

A series of bivariate scatter plots were investigated to verify the assumptions of linearity and homoscedasticity. The distribution of residuals was also inspected as an additional procedure to check for homoscedasticity. A visual inspection of these scatterplots confirmed linear relationships between all variables. The scatter plots, together with the inspection of the residual distributions, confirmed that the homoscedasticity assumption was not violated in the current data set.

Zero-order correlations between predictor variables were all well below .90, which suggests no problems of multicollinearity. Further, all tolerance values for predictors across regression models were above .90; therefore, multicollinearity and singularity were not present.

Preliminary Analyses

Descriptive statistics and Zero-Order Correlations. Descriptive statistics for all variables included in the regression analyses are presented in Table 2. A recent Canadian Campus Survey conducted on undergraduate students found that, on average, students drink about 6 standard drinks per week (Adlaf, Demers, & Gliksman, 2004). With respect to alcohol-related problems, recent work by Read et al., (2006) found that students in the U.S. reported experiencing a mean of M = 14.7 (SD = 7.80) problems associated with alcohol use in the past 12-months. Compared to the existing literature, the present sample reported a lower number of mean standard drinks consumed per week, and a lower average number of alcohol-related problems in the past year.

Pearson correlations were examined between all variables included in the regression analyses (see Table 2). Of note, the BAS Drive and BAS Fun Seeking subscales were both significantly positively associated with weekly alcohol use and alcohol-related problems. The BAS Reward Responsivity subscale was significantly positively correlated with alcohol-related problems. In contrast, the FFFS subscale was significantly negatively associated with alcohol-related problems, but not alcohol use. The BIS self-report subscale was not significantly correlated with either of the alcohol misuse outcomes.

With respect to the zero-order relations between the five self-report subscales and the MFT trial types, there was a statistically significant negative correlation between self-report BAS Fun Seeking and positive congruent trial residuals (controlled for neutral congruent baseline) from the MFT. This suggests that higher scores on BAS Fun Seeking were associated with faster reaction times to pure reward trials from the MFT. The correlation between self-report BIS and incongruent trial residuals on the MFT was not statistically significant. Furthermore, there was no statistically significant association between self-report FFFS and negative congruent trial residuals from the MFT. Based on zero-order correlations, reaction times on the different trial types from the MFT were not significantly correlated with alcohol-related problems or average weekly alcohol use.

MFT word valence ratings. Average valence ratings for the words used in the MFT are presented in Table 3. The means for each word fell in the expected valence range: positive words had means between 7 (quite positive) and 9 (extremely positive); negative words had means between 1 (extremely negative) and 3 (quite negative); and the means for neutral words fell between 4 (slightly negative) and 6 (slightly positive).

Hypothesis Testing

Confirmatory factor analysis. The following five-factor model was specified: 4-item BIS, 3-item FFFS, 5-item BAS Reward Responsivity, 4-item BAS Drive and 4-item-BAS Fun Seeking. Correlations were estimated between the latent factors. Positive correlations were expected between the three BAS factors. Weak correlations were expected between the BAS factors and the BIS factor, as these systems are relatively orthogonal according to theory. Also, weak correlations were expected between BAS factors and the FFFS factor. Finally, a positive association was hypothesized between the BIS and FFFS factors.

The initial full model had poor fit to the data ($\chi^2_{(46)}$ = 101.64, p=.00, CFI=.87, TLI=.88, RMSEA = .10). Upon further inspection of the model, it was found that two items on the BAS Reward Responsivity factor (“When I'm doing well at something I love to keep at it”; “It would excite me to win a contest”) and one item (“If I think something unpleasant is going to happen I usually get pretty "worked up") on the FFFS factor had poor factor loadings (< .50). The problematic BAS Reward Responsivity items in the present study are inconsistent with previous work on this scale (e.g., Heym, Ferguson and Lawrence, 2008; Beck et al., 2009). However, one could argue that these items also seem to reflect aspects of fun seeking ("…win a contest") and drive ("When I'm doing well at something *I love to keep at it*). As such, these items were dropped from the model. The problematic item on the FFFS factor was dropped because conceptually, this item may reflect both sensitivity to punishment cues ("If I think something bad is going to happen…") and an anxiety response ("…get pretty 'worked up'"). This two-item FFFS factor is consistent with the findings of some published studies in the extant literature (Johnson, Turnen, Iwata, 2003; Polythress et al., 2009). When the three problematic items were trimmed from the model, fit improved ($\chi^2_{(40)}$ = 74.94, p=.00, CFI=.94, TLI=.95, RMSEA = .07). The final 17-item model is presented in Table 4, and the factor correlations are presented in Table 5. Items in the final model showed adequate factor loadings according to Comrey and Lee (1992)'s guidelines described above. Despite concerns with the relatively low item-factor ratios (e.g., two-item FFFS), the indicator-factor correspondence in the specified CFA was used to create composite means for each self-report subscale.

Validation of the MFT. Once the five self-report subscales were created, a series of hierarchical regression analyses were conducted using critical trials from the MFT as criterion variables. Overall medians for each critical trial type on the MFT are presented in Appendix C. First, to test the hypothesis that reaction times to positive congruent trials would relate negatively to scores on the self-report BAS subscales and reward trials on the PSRTT only, positive congruent trial reaction times were regressed on neutral congruent control trials (covariate), the five self-report subscales and PSRTT reward residual scores (see Table 6). This model accounted for about 67% of the variance, and self-report BAS Fun Seeking and neutral congruent control trials were found to be statistically significant predictors. Higher scores on BAS Fun Seeking were associated with faster reaction times on positive congruent trials. Surprisingly, PSRTT reward residuals did not significantly predict variation on reaction times for positive congruent trials from the MFT.

To test the hypothesis related to how the MFT captures BIS, reaction times for incongruent trials of interest (i.e., positive targets flanked by negative distracters) were regressed on incongruent control trials, the five self-report subscales, and PSRTT conflict residuals (see Table 6). This model accounted for 85% of the variance, and self-report BIS, PSRTT conflict residuals, and incongruent control trials were found to be statistically significant predictors. Higher scores on self-report BIS and PRSTT conflict residuals were associated with slower reaction times on incongruent trials on the MFT. This finding supports the present study's hypotheses regarding how the MFT should tap the revised BIS, such that when motivational conflict is present, individuals with strong BIS should be momentarily inhibited, leading to slower reaction times.

Some may argue that based on the above model results; there is no evidence to suggest that the MFT improves the measurement of the revised BIS above and beyond existing laboratory tasks (i.e., the PSRTT). To test this notion, an additional regression model was conducted to test if the BIS factor derived from the CFA uniquely predicted variation on PSRTT conflict residuals. It should be noted that the CFA adequately separated a BIS and a FFFS factor. Consequently, one could argue that the BIS factor obtained in the present study is more consistent with the revised RST. As seen in Table 7, the BIS factor did not predict PSRTT conflict residuals.

Finally, to test the hypothesis that only high FFFS would be inversely associated with responses to punishment trials, negative congruent trial reaction times were regressed on neutral congruent control trial reaction times and the five self-report subscales (see Table 6). This model accounted for approximately 72% of the variance, and neutral congruent control trials emerged as the only statistically significant predictor. Contrary to hypotheses, self-report FFFS was not associated with faster reaction times to negative target words (i.e., stimuli signalling pure punishment). As mentioned previously, the self-report FFFS measure derived from the Carver and White's (1994) BIS/BAS Scales was comprised of only two-items. As a result, this subscale had relatively poor internal consistency. To evaluate how the MFT measures punishment sensitivity, a more reliable and stable comparison measure is needed.

Three additional regression models were conducted to evaluate the remaining trial types on the MFT against the five self-report subscales and the PSRTT. It should be noted that there were no apriori hypotheses regarding these trials, so these analyses were exploratory in nature. In the first regression analysis, single positive trial reaction times were specified as the criterion, with single neutral control trial reaction times, the five self-report subscales and PSRTT reward residuals as predictors. Conceptually, responses to single positive words (i.e., reward) should capture BAS strength. This model accounted for approximately 65% of the variance, and BAS Fun Seeking (β = -17.40, *SE* = 7.45, *p* = .002), BAS Reward Responsivity (β = 18.08, *SE* = 9.05, *p* = .05) and single neutral control trials (β = .81, *SE* = .64, $p < .001$) emerged as statistically significant predictors. In this model, PSRTT reward residuals were found to be marginally significant (β = .08, *SE* = .05, p = .09). Higher BAS Fun Seeking scores and lower PSRTT reward residuals were associated with faster reaction times to reward trials on the MFT. Interestingly, higher scores on BAS Reward Responsivity were associated with slower reaction times to single positive targets. Next, single negative trial reaction times were specified as the criterion with single neutral control trials, and the five self-report subscales as predictors. Theoretically, reactions to punishment cues should capture FFFS sensitivity. Single neutral control trials (β = 1.01, *SE* = .06, $p < .001$) emerged as the only significant predictor in this model. Last, another model was conducted looking at the other type of incongruent trials (i.e., negative targets flanked by positive distracters) as the outcome. Reaction times on these trials may reflect BIS activation due to the presence of motivational conflict. This model accounted for 89% of the variance, and BAS Drive (β = -8.62, *SE* = 4.49, p = .06) was found to be negatively associated with reaction times. Higher scores on BAS Drive were associated with faster reaction times on these incongruent trials. The presence of possible reward may have facilitated individuals with a strong BAS to respond more quickly to the target stimuli.

Testing the interactive effects of the revised systems on alcohol misuse Outcomes. To test the hypothesis that BAS would moderate the association between BIS and alcohol misuse, tests of moderation were conducted. Specifically, it was hypothesized that high BIS, together with high BAS, would lead to greater risk for heavy drinking and experiencing alcohol related problems. Of central interest were two moderation models using BIS and BAS residual scores from the MFT to predict the alcohol misuse outcomes. Like with the PSRTT, each set of residual scores were created by conducting simple regressions with each critical trial type as the criterion and each respective control trial as the predictor. Unstandardized residual scores for both BAS and BIS trial types were saved to the data set in order to run the moderation analyses. The BIS by BAS interaction term was created by taking the product of both sets of residual scores. The first test of moderation was conducted using a hierarchical regression model which included two steps. The predictor variables were entered into the model first, followed by the two-way interaction to predict average number of alcohol-related experienced in the past year. As presented in Table 8, first order effects of BAS and BIS were not statistically significant. The two-way BIS by BAS interaction was also not statistically significant.

Despite non-statistical significance of the two-way BIS by BAS interaction, simple slopes analyses revealed an appreciable positive, but non-statistically significant association between BIS and alcohol-related problems at high levels of BAS ($B = .05$, $SE = .03$, $p = .07$, $f^2 = .023$) (see Figure 2a). Conversely, at low levels of BAS, the association between BIS and alcohol-related problems was non-statistically significant ($B = .01$, $SE = .01$, $p = .71$, $f^2 = .001$) (see Figure 2a). Although the overall interaction was non-significant, the direction and magnitude of the simple slopes provided support for the current hypotheses. A second test of moderation was conducted using the same predictor variables, but specifying average weekly alcohol use as the criterion. As presented in Table 8, first order effects of BAS and BIS were statistically significant. The two-way BIS by BAS interaction was also statistically significant. Follow up simple slopes analyses revealed a statistically significant positive association between BIS and average weekly alcohol use at high levels of BAS (β = .06, *SE* = .02, p = .002, f^2 = .07) (see Figure 2b). This effect was not observed when the model was conditioned on low levels of BAS (β = .01, *SE* = .02, p = .67, f^2 < .001) (see Figure 2b). Again, the pattern and magnitudes of the simple slopes were in line with the hypotheses of the current study.

Subsequent moderation analyses were conducted to explore how three different aspects of BAS (i.e., drive, fun seeking, and reward responsivity) moderate the association between BIS and alcohol misuse. To the author's knowledge, this is the first study to test these relations. In all of these models, BIS was measured using incongruent residual scores from the MFT. Broadly, the combination of high BIS *and* high BAS only was expected to be positively and statistically associated with greater levels of alcohol misuse.

First, BAS Drive was tested as a potential moderator of the relation between BIS and alcohol-related problems (criterion). As seen in Table 9, there was evidence for an appreciable interaction effect. Simple slopes analyses revealed that BIS was positively associated with alcohol-related problems, but only at high levels of BAS Drive (β = .06, *SE* = .03, p = .03, f^2 = .03) (see Figure 3a). Next, a second moderation analysis was conducted to investigate how the BIS by BAS Drive interaction predicted average weekly alcohol use. As observed in Table 9, the interaction term was statistically significant. Simple slopes analyses showed that there was a strong positive relation between BIS and average weekly alcohol use at high levels of BAS (β = .07, *SE* = .02, p < .001, f^2 = .11) (see Figure 3b). This association was not observed when the model was conditioned on low levels of BAS Drive (β = -.03, *SE* = .02, p = .15, f^2 = .01) (see Figure 3b). Taken together, these results indicate that BAS Drive moderates the relation between BIS and alcohol misuse.

Second, BAS Fun Seeking, BIS and the interaction term was regressed on alcohol-related problems (see Table 10). The overall model accounted for 15% of the variance, but the BAS Fun Seeking by BIS interaction was not statistically significant. The simple slopes for BIS on alcohol-related problems at high (β = .01, *SE* = .03, *p* = .63, f^2 = .001) and low (β = .03, *SE* = .03, *p* = .27, f^2 = .001) were not statistically significant (see Figure 4a), and both slopes corresponded to relatively small effect sizes. Next, a test of moderation was conducted using average weekly alcohol use as the criterion, and BAS Fun Seeking, BIS and the interaction term as predictors in the model. As seen in Table 10, the overall model accounted for 10% of the variance, and the interaction term was statistically significant. Follow up simple slopes analyses indicated that there was a strong positive association between BIS and average weekly alcohol use only at high (β = .05, *SE* = .02, *p* = .005, f^2 = .06) but not low (β = -.01, *SE* = .02, *p* = .70, f^2 < .001) BAS Fun Seeking (see Figure 4b). Overall, it was found that BAS Fun Seeking moderates the relation between BIS and alcohol use, but not alcohol-related problems, in the expected direction. It should be noted that this is consistent with the earlier moderation analyses using the MFT BIS and BAS residuals. Given that positive congruent trials on the MFT seemed to be capturing fun seeking, one would expect similar model results using each measure of BAS as a moderator between the association between BIS and alcohol misuse outcomes.

Last, the remaining BAS construct, reward responsivity, was tested as a moderator of the relation between BIS and alcohol misuse. In the first model, BIS, BAS

Reward Responsivity and the interaction term were entered as predictors of alcohol-related problems. As seen in Table 11, the interaction effect was not statistically significant and did not account for more variance above and beyond the first order effects of BIS and BAS Reward Responsivity. Despite the non-significance of the interaction term, the model was probed further. The association between BIS and alcohol-related problems at high (β = .01, *SE* = .04, *p* = .87, f^2 = .001) and low (β = .02, *SE* = .02, *p* = .29, f^2 = .002) BAS Reward Responsivity were non-statistically significant (see Figure 5a). Next, a similar test of moderation was conducted using average weekly alcohol use as the criterion variable. There was evidence for an appreciable BIS by BAS Reward Responsivity interaction effect (see Table 11). Simple slopes analyses revealed a statistically significant positive association between BIS and average weekly alcohol at high (β = .07, *SE* = .03, *p* = .004, f^2 = .06), but not low (β = .03, *SE* = .01, *p* = .07, f^2 = .02) BAS Reward Responsivity (see Figure 5b). It was observed that strong BIS, together with strong BAS Reward Responsivity, were associated with greater weekly alcohol use, but not alcohol-related problems. In sum, the results of the moderation analyses above support the hypothesis that BAS moderates the association between BIS and alcohol misuse outcomes.

Discussion

The primary goal of the current study was to validate a novel and theoretically-derived reaction time task of the revised RST, called the MFT. The MFT was designed to capture individual differences in the strength of all three motivational systems - the BAS, BIS, and FFFS - with a specific emphasis on measuring the BIS as a motivational conflict system. As mentioned previously, existing laboratory tasks of the revised RST have several limitations. First, these tasks do not measure BIS conflict at the motivational or goal-level. According to theory, reward and punishment cues need to be presented simultaneously in order to evoke BIS activation (Corr, 2008). Second, tasks in the extant literature tend to measure only BAS and BIS strength (e.g., the PSRTT), and therefore, neglect the assessment of FFFS. The MFT was created to address these limitations, and therefore, improve the laboratory assessment of the revised RST.

The MFT was validated against one promising self-report measure of the RST, Carver and White's (1994) BIS/BAS Scales. Previous studies have found that the BIS/BAS Scales have a factor structure that is consistent with the revised theory – that is, the scale has distinct BIS, BAS and FFFS factors (Heym, Ferguson and Lawrence, 2008; Beck et al., 2009). In the present study, a CFA replicated this factor structure. When the MFT was investigated in relation to these factors, it was found that elevated scores on BAS Fun Seeking were associated, as expected, with fast responses to cues of pure reward (i.e., positive congruent trials). Also, in line with hypotheses, it was found that elevated scores on self-report BIS were uniquely associated with slow reaction times on incongruent trials on the MFT which presented motivational conflict. Contrary to hypotheses, elevated scores on the FFFS scale were not associated with fast reaction times to negative congruent trials on the MFT, which signalled opportunities for punishment.

The second goal of the present study was to clarify the relation between BIS and alcohol misuse by looking at the moderating role of BAS. More precisely, it was hypothesized that a strong BIS, together with a strong BAS, would be associated with high levels of weekly alcohol use and more alcohol-related problems. In light of the previous results, BIS and BAS trial types from the MFT were used in the primary moderation model of interest in predicting alcohol misuse outcomes. It was found that a strong BIS was associated with elevated weekly alcohol use, and more alcohol-related problems, at high BAS, albeit this effect was weaker for alcohol-related problems. Subsequent analyses revealed a similar pattern of association between BIS and alcohol misuse, as moderated by different facets of BAS. With the exception of BAS Drive, the high BIS positively predicted elevated weekly alcohol use, but not alcohol-related problems, at high levels of BAS. Consistent with hypotheses and recent empirical work (Wardell, O'Connor, Read & O'Connor, 2011; Keough & O'Connor, 2011), these findings serve to clarify the personality composite that gives rise to greater risk for alcohol misuse.

The MFT and the Revised RST

Broadly, the results of the current study support the potential of the MFT as a promising and theoretically informed measure of the revised RST. Conceptually, the MFT improves on existing tasks because it explicitly measures the revised BIS as a conflict detection and resolution system. According to theory, the BIS is activated only by the presence of motivational or goal-level conflict (Corr, 2002; 2008). That is, reward and punishment cues must occur *at the same time* before approach or avoidance behaviour is initiated. To the author's knowledge, the MFT is the first task of the revised BIS that explicitly presents simultaneous conflicting reward and punishment cues and requires participants to make decisions. In this respect, the MFT represents theoretical advancement in the laboratory assessment of the revised RST. Current tasks designed to measure the RST do not evoke goal-level conflict. For example, some authors have used a classic Go/No-Go Task to capture BIS strength (Amodio, Master, Lee & Taylor, 2008; De Pascalis,Varriale & D'Antuono, 2010; Wacker et al., 2010). However, in the Go/No-Go Task, the conflict occurs at the response level (i.e., selection of Go versus No-Go response) and greater commission errors (i.e., responding to No-Go cues) reflects impulsivity. Moreover, participants are not rewarded or punished for their responses Go/No-Go Tasks, and thus, the classic Go/No-Go paradigm lacks the motivational components to capture BIS conflict.

The results of the present study also suggest that the MFT may better tap BIS conflict than the PSRTT. The PSRTT was developed as a behavioural task of the revised RST in children (Colder et al., 2011). During the PSRTT, a cue is shifted from being associated with punishment (*punishment block*) to being associated with reward (*post punishment block*). Specifically, before the punishment block, participants are told that if they respond at all when a green circle is present then they will lose 50% of their accumulated points. Next, before the post punishment block, participants are told to respond as fast as they can, even when green circles are present, because quicker correct responses will earn them more points. According to the authors of the task, this should create conflicting inputs from the FFFS and the BAS, thus resulting in BIS activation and slowed reaction times for green circle trials in the post punishment block (Colder et al., 2011). Consistent with this interpretation, the present study found that participants were slower to respond to green circle trials in the post punishment block compared to reward trials directly preceding the green circle trials. This slowing in reaction time was positively associated with incongruent trial reaction times on the MFT, but was not associated with the self-report BIS factor. The CFA parsed out FFFS items from the original BIS subscale, leaving items that seem to reflect the revised BIS in terms of uncertainty and anxiety ("I worry about making mistakes"). Consequently, one could argue that this revised self-report BIS subscale is a good starting point to begin to validate new laboratory measures of the revised BIS. As such, the present study found that elevated scores on self-report BIS were positively associated with slower reaction times to incongruent trials on the MFT, but not to green circle conflict trials on the PSRTT.

One potential reason for this finding is a methodological difference between the PSRTT and the MFT in measuring the BIS. In the PSRTT, green circle trials are initially associated with large potential punishment (i.e., losing 50% of accumulated points). When these cues shift to being associated with reward, those who are punishment sensitive may still be more sensitive to the potential of losing points. In this respect, the green circle trials may not be the best way to tap the BIS because the potential for punishment may be *more salient* than the potential for reward. As Corr (2002; 2005; 2008) argues, equal activation of the FFFS and BAS is needed to engage BIS conflict resolution. As such, in the MFT, reward and punishment cues are brought together simultaneously in equal strength to measure the revised BIS. Thus, the author of the present study argues that the MFT is a better conceptual measure of BIS conflict than the PSRTT and other existing tasks. Results from the current study support this assertion preliminarily; however, more empirical work is needed to rigorously test the MFT's measurement of BIS.

Contrary to hypotheses, fast reaction times to negative congruent trials (i.e., cues of pure punishment) were not associated with high scores on the self-report FFFS subscale. There are at least two potential reasons for this finding. First, the comparison measure for these trials, the self-report FFFS subscale, was comprised of only two items, and hence, had relatively low internal consistency. It should be noted that the two-item FFFS subscale is consistent with studies in the published literature (Johnson, Turnen, Iwata, 2003; Polythress et al., 2009). In future work, a stronger composite measure of the FFFS is needed to evaluate how well the MFT captures punishment sensitivity. Second, the MFT differs methodologically from existing measures of FFFS strength. According to theory, those with a strong FFFS are sensitive to punishment cues, and this promotes feelings of fear and subsequent avoidance behaviour. Along these lines, some authors have exposed participants to aversive stimuli (e.g., mild shock, or loud noise) and measured the corresponding physiological and subjective fear responses (Corr, 2008). Alternatively, Perkins and Corr (2006) presented participants with threat scenarios (e.g., "Being attacked in a car") and asked them to rate how they would respond to each event, such as "run away". In contrast, the MFT asks participants to "approach" or respond to cues that signal opportunities of punishment. The rationale behind this was that individuals who have a strong FFFS should be fast to detect punishment cues, and hence, "get rid of this threatening information" by responding quicker than those who are low in FFFS. This is a theoretically-derived prediction. However, this hypothesis was not supported by the current data. Revisions to the task may be necessary; however, this is difficult to assess given the poor reliability of the FFFS factor as the comparison measure.

The Interactive Effects of BIS and BAS and Alcohol Misuse

With respect to extant literature, the present study sheds new light on the complex influence of BIS on alcohol misuse behaviour. Empirical support for the negative reinforcement pathways to alcohol misuse is inconsistent, with some research finding that elevated BIS is associated with increased (O'Connor, Stewart, & Marlatt, 2009) or decreased alcohol misuse risk (Kimbrel, Nelson-Gray, & Mitchell, 2007) and others demonstrating no relation (Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008). In the current sample, there were no significant zero-order correlations between BIS measures (self-report or behavioural) and alcohol misuse outcomes. According to the revised RST, in order to understand BIS risk for alcohol misuse, one needs to consider the moderating effects of BAS and FFFS. Recent evidence suggests that BAS moderates the association between BIS and prospective alcohol misuse (Wardell, O'Connor, Read & Colder, 2011). Specifically, these authors found that a strong BIS was positive associated with prospective alcohol use and alcohol-related problems, at high levels of BAS. However, this effect was stronger for alcohol-related problems than alcohol use.

Consistent with the joint subsystems hypothesis and recent data, the current study found that BIS was consistently linked to average weekly alcohol use, at high levels of BAS. This pattern of association was observed in several separate moderation models, where different measurements of BAS (i.e., positive congruent trial reaction times on the MFT and three self-report BAS factors) were tested as moderators. The relation between BIS and alcohol-related problems was inconsistent in the current data. More precisely, there was a positive association between BIS and alcohol-related problems, when BAS Drive and positive congruent trial reaction times from the MFT were used as moderators. This relation was not found when BAS Fun seeking and BAS Reward Responsivity were used as moderators. On the whole, it appears that the high BIS/high BAS combination is a risk factor for greater alcohol consumption, but not necessarily for experiencing more alcohol-related problems.

In the current study, the inconsistent association between BIS and alcohol-related problems, at high levels of BAS, may be explained by individual differences in *perceptions* of alcohol-related problems. In the alcohol misuse literature, researchers have identified distinct classes of negative alcohol-related problems in students (Read, Kahler, Strong & Colder, 2006). However, some work suggests that not all individuals rate certain alcohol-related problems as negative (Mallett, Bachrach, & Turrisi, 2008). These authors found that students were less likely to rate blacking out and missing classes as negative consequences of heavy drinking. In fact, more than 10% of the sample rated these outcomes as positive, and an additional 30% rated these as neutral outcomes. Applying these findings to the present results, anxious individuals (high BIS), who are also very reward responsive (high BAS), may drink heavily in social contexts and may view consequences, like blacking out, as normative or even as a means to “fit in and be cool”. Also, individuals who have a strong BAS are likely to be impulsive and enjoy engaging in risk taking behaviours (e.g., binge drinking). These individuals may view so-called negative consequences as evidence of having a good time. This possibility may be reflected in the current study, as participants endorsed a relatively low number of alcohol-related problems experienced in the past year, compared to previous studies (Read et al., 2006). This effect may be even greater for students who have a strong BAS. These possibilities need to be tested in future empirical work on the revised RST and alcohol-related problems.

Limitations

There are several limitations of the present study. First, the sample size was relatively small to run a CFA with item level data. According to Kline (personal communication, 2011), the minimum ratio of cases per indicator in a factor analyses is 10:1; however, this sample size requirement increases with item level data. This is because items are less reliable than scale level data. Throughout this paper, the author was careful not to over-interpret the results based on the CFA for this very limitation. A second limitation was the small item pool on Carver and White's (1994) BIS/BAS Scales, which negatively influenced the reliability of the factors. Ideally, future studies will address this limitation by using larger questionnaires designed to explicitly measure the revised RST. It should be noted that the use of the BIS/BAS Scales in the current study represents the first step in refining measures to suit the revised theory.

Implications and Future Directions

This study has several basic and clinical implications. Primarily, the MFT appears to be a promising behavioural measure of personality. In the body of literature on personality, individual differences in motivational sensitivities are typically captured through self-report questionnaires, such as Carver and White's (1994) BIS/BAS Scales. Although these measures have scientific and theoretical merit, they are limited because they are somewhat removed from reflexive or *in-the-moment* behavioural responses towards reward, punishment or motivational conflict thought to underlie risk for alcohol misuse. To expand on this, alcohol misuse behaviour may be initiated somewhat automatically (i.e., impulsively, without cognitive reflection) in anxious individuals who are especially reward responsive. The MFT represents a step forward in measuring motivational sensitivities at the behavioural level, and understanding these behavioural processes may help clarify etiological risk models of alcohol misuse. Second, the MFT offers researchers a valid conceptual measure of the revised BIS. Accordingly, pending future successful work on the MFT, researchers and practitioners can use the MFT in laboratory settings to measure the revised BIS in young adults. The present study showed that BIS measurement in the MFT clarified risk for alcohol misuse. Extending this finding, the MFT may serve to clarify the role of BIS in risk for various psychopathologies in young adulthood (e.g., anxiety disorders, depression). Future work would be needed to test the MFT's applicability to child samples.

Clinically, the present study sheds light on the negative reinforcement pathway to alcohol misuse in students. The major finding was that anxious individuals (high BIS), who are also very reward responsive (high BAS), showed elevated levels of weekly alcohol misuse, and to a lesser extent experienced more alcohol-related problems. In this respect, this study informs clinical interventions, such that coping-motivated drinkers may benefit from treatments aimed at slowing down the automaticity of the process, while increasing the salience of negative alcohol outcomes.

Future empirical work should expand on the current study in several ways. First, the MFT will be validated against a newly developed measure of the revised RST, called the Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ). The RST-PQ is an 84-item self-report questionnaire created that measures all three revised motivational systems. This measure is currently unpublished; however, preliminary work suggests that it has good psychometric properties (Corr, personal communication, 2012). Furthermore, an exploratory factor analyses and a subsequent confirmatory factor analysis revealed a six factor structure: four BAS factors (7-item Reward Interest, 7-item

Goal-Drive Persistence, 10-item Reward Reactivity, and 8-item Impulsivity), a 23-item revised BIS factor, and a 10-item FFFS factor (Corr & Cooper, in prep). Compared with Carver and White's (1994) BIS/BAS Scales, the RST-PQ will be a better validation tool for the MFT for two main reasons. One, the RST-PQ was developed based on the revised RST, whereas the BIS/BAS Scales were created under the original RST to measure only sensitivity to reward and sensitivity to punishment. Therefore, the BIS/BAS Scales do not explicitly contain items related to measuring BIS as a motivational conflict system. Two, the RST-PQ factors have a larger number of indicators, which will likely result in more stable factors with higher internal consistencies. In the current study, the RST-PQ was included in data collection midway through the year; therefore, data collection needs to continue in order to get a sufficient amount of cases to run an exploratory factor analysis. Once this is complete, the author will investigate how these factors relate to performance on the MFT.

Second, future studies should aim to investigate the potential moderating role of the FFFS on the relation between BIS and alcohol misuse. Examining the role of the FFFS in the negative reinforcement pathway to alcohol misuse may clarify the possible protective influence of BIS on drinking behaviour (Wardell, O'Connor, Read & Colder, 2011). According to the revised RST, individuals with a strong FFFS are sensitive to cues of punishment, so the negative consequences of drinking alcohol should be should be more salient for these persons. Consequently, a strong FFFS may interact with BIS to resolve conflict in favour of avoiding alcohol use. To the author's knowledge, no published studies have tested this possibility.

Conclusion

In conclusion, the present study found that the MFT improves the measurement of the revised BIS as a motivational conflict resolution system. Also, using the MFT and self-report measures of the RST, the present study provided support for the BIS by BAS interaction in predicting alcohol use and alcohol-related problems. Taken together, these results suggest that the MFT helps to clarify the relation between BIS and risk for alcohol misuse in university students.

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Table 1

Summary of effect size measures for word categories

Mean Contrast	Length	Syllable	Subtitle Frequency
Positive - Negative	.06	.24	.11
Positive - Neutral	.12	-.20	.06
Negative - Neutral	.05	-.44	.08

Note. The pooled within group standard deviation was used as the standardizer for all effect size calculations. All values are d-type effect sizes.

Table 2

Zero-Order Correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. BAS Drive	1.00											
2. BAS Fun Seeking	.44†	1.00										
3. BAS Reward Responsivity	.34†	.36†	1.00									
4. Self-Report BIS	-.12	-.21*	.16	1.00								
5. Self-Report FFFS	-.21*	-.27*	.01	.46†	1.00							
6. Positive Congruent Residuals (BAS) MFT	-.03	-.21*	.01	.14	.04	1.00						
7. Incongruent Residuals (BIS) MFT	.05	.08	-.01	.12	.19†	.26†	1.00					
8. Negative Congruent Residuals (FFFS) MFT	.08	-.03	.07	-.02	.04	.47†	.19†	1.00				
9. PSRTT Reward Residuals	-.1	.03	.05	-.06	.06	.06	.01	.12	1.00			
10. PSRTT Conflict Residuals	-.02	-.02	-.04	-.03	.04	.06	.16*	.14	.11	1.00		
11. Weekly Alcohol Use	.15*	.26†	.07	.03	-.01	-.11	.14	-.11	.01	.01	1.00	
12. Alcohol-Related Problems	.23†	.37†	.16*	-.01	-.14*	-.02	.11	-.08	.01	-.04	.52†	1.00
M	2.68	3.04	3.51	3.30	2.93	.00	.00	.00	.00	.00	11.08	9.01
SD	.59	.52	.41	.55	.74	41.52	29.22	40.29	80.34	96.87	14.34	7.72

Note. BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; FFFS=Flight, Fight, Freeze System; PSRTT=Point Scoring Reaction Time Task.

*p<.05

†p<.01

Table 3

Average Word Valence Ratings

Positive	Mean	SD	Negative	Mean	SD	Neutral	Mean	SD
Adorable	7.90	1.01	Poor	2.50	1.11	Letter	5.10	.28
Funny	8.10	.80	Mistakes	2.60	1.15	Library	5.10	.60
Delight	8.70	.88	Disease	1.60	.85	Computer	5.10	.50
Humour	7.90	.94	Awful	1.70	.84	Lift	5.10	.52
Smile	8.20	.90	Threat	2.20	1.15	Dictionary	5.10	.43
Laughter	8.10	.97	Difficult	2.80	1.13	House	5.20	.58
Happy	8.30	.97	Fear	2.40	1.12	Diary	5.10	.45
Trust	7.60	1.10	Afraid	2.30	1.11	Ticket	4.90	.64
Pleasant	7.70	.87	Terrible	1.80	.96	Pages	5.00	.16
Exciting	8.20	.78	Suffer	1.70	1.05	Magazine	5.00	.45

Note. Means between 7 and 9 indicate positive valence ratings. Means between 1 and 3 indicate negative valance ratings. Means between 4 and 6 indicate neutral valence ratings.

Table 4

Summary of the Confirmatory Factor Analysis of the BIS/BAS Scales (N=150)

	Unstand. Loading	Stand. Loading	Residuals
Indicators of the BAS Drive Factor			
3. I go out of my way to get things I want.	1.0 (.00)	.74	.46
9. When I want something I usually go all-out to get it.	1.1 (.08)	.81	.34
12. If I see a chance to get something I want I move on it right away.	1.18 (.09)	.87	.24
21. When I go after something I use a "no holds barred" approach.	1.08 (.09)	.79	.37
Indicators of the BAS Fun Seeking Factor			
5. I'm always willing to try something new if I think it will be fun.	1.00 (.00)	.76	.42
10. I will often do things for no other reason than that they might be fun.	.81 (.09)	.61	.63
15. I often act on the spur of the moment.	.79 (.13)	.60	.64
20. I crave excitement and new sensations.	.99 (.11)	.75	.44
Indicators of the BAS Reward Responsivity Factor			
7. When I get something I want, I feel excited and energized.	1.00 (.00)	.73	.47
14. When I see an opportunity for something I like I get excited right away.	1.3 (.21)	.95	.10
18. When good things happen to me, it affects me strongly.	.72 (.12)	.53	.72
Indicators of the BIS Factor			
8. Criticism or scolding hurts me quite a bit.	1.0 (.00)	.63	.61
13. I feel pretty worried or upset when I think or know somebody is angry at me.	1.14 (.19)	.71	.49
19. I feel worried when I think I have done poorly at something important.	.96 (.16)	.60	.63
24. I worry about making mistakes.	1.10 (.18)	.70	.52
Indicators of the FFFS Factor			
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.	1.00 (.00)	.73	.47
22. I have very few fears compared to my friends.	1.06 (.17)	.77	.41

Note. Five factor CFA model of the BIS/BAS Scales ($\chi^2_{(40)}$ = 74.94, p=.00, CFI=.94, TLI=.95, RMSEA = .07). Unstand. = Unstandardized factor loadings; Stand. = Standardized factor loadings. Standard errors of the unstandardized parameters are in brackets.

Table 5

Correlations between BIS/BAS Scale Factors

Factor	1	2	3	4	5
1. BAS Drive	1.00				
2. BAS Fun Seeking	.34	1.00			
3. BAS Reward Responsivity	.29	.31	1.00		
4. BIS	-.06	-.15	.13	1.00	
5. FFFS	-.17	-.24	.00	.33	1.00

Note. BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; FFFS=Flight, Fight, Freeze System as measured by Carver and White's (1994) BIS/BAS Scales.

Table 6

Summary of MFT Critical Trials Regressed on BIS/BAS Self-Report Subscales and PSRTT Trial Types

Predictors	*B*	*SE*	Beta	R^2	*t*	*p*
Positive Congruent Reaction Times (criterion)						
Control Trials	.85	.06	.76		13.48	<.001
BAS Drive	4.95	6.73	.04		.74	.46
BAS Fun Seeking	-20.51	7.84	-.15		-2.62	.01
BAS Reward Responsivity	6.09	9.53	.04		.64	.52
BIS	8.78	7.12	.07		1.22	.22
FFFS	-3.99	5.31	-.04		-.75	.45
PSRTT Reward Residuals	.06	.05			1.21	.23
				.67[.59-.75][a]		
Incongruent Reaction Times (criterion)						
Control Trials	.89	.03	.93		27.27	<.001
BAS Drive	2.07	4.70	.02		.44	.66
BAS Fun Seeking	7.44	5.55	.05		1.34	.18
BAS Reward Responsivity	-7.38	6.90	-.04		-1.07	.29
BIS	10.98	5.03	.83		2.18	.03
FFFS	-2.83	3.71	-.03		-.76	.45
PSRTT Conflict Residuals	.05	.03	.07		2.00	.05
				.85[.81-.89][a]		
Negative Congruent Reaction Times (criterion)						
Control Trials	1.01	.06	.84		18.56	<.001
BAS Drive	5.72	6.64	.05		.86	.39
BAS Fun Seeking	-9.03	7.73	-.06		-1.17	.25
BAS Reward Responsivity	8.43	9.47	.05		.89	.38
BIS	-1.44	7.05	-.01		-.21	.84
FFFS	-3.08	5.23	-.03		-.59	.56
				.72[.64-.79][a]		

Note: The control trial variable was entered as a covariate. PSRTT=Point Scoring Reaction Time Task; BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; FFFS=Flight, Fight, Freeze System as measured by Carver and White's (1994) BIS/BAS Scales.

[a]95% confidence interval

Table 7

Summary of PSRTT Conflict Residuals Regressed on BIS/BAS Self-Report Subscales

Predictors	*B*	*SE*	Beta	R^2	*t*	*p*
BAS Drive	-.18	15.81	-.01		-.01	.99
BAS Fun Seeking	-1.77	18.48	-.01		-.01	.92
BAS Reward Responsivity	-6.73	22.59	-.03		-.29	.77
BIS	-9.54	16.92	-.05		-.56	.57
FFFS	7.51	12.55	.06		.59	.55
				.005[.0-.03][a]		

Note: PSRTT=Point Scoring Reaction Time Task; BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; FFFS=Flight, Fight, Freeze System as measured by Carver and White's (1994) BIS/BAS Scales.

[a]95% confidence interval

Table 8

Summary of alcohol misuse outcomes regressed on BIS and BAS residual terms from the MFT

Predictors	*B*	*SE*	Beta	R^2	R^2 change	*t*	*p*
Alcohol-Related Problems (Criterion)							
BAS residuals MFT	-.01	.02	-.06			-.69	.49
BIS residuals MFT	.03	.02	.12			1.44	.15
				.015[0-.05][a]			
BIS X BAS	.00	.00	.09			1.04	.30
				.02[0-.06][a]	.005		
Average Weekly Alcohol Use (Criterion)							
BAS residuals MFT	-.02	.01	-.17			-2.01	.04
BIS residuals MFT	.04	.02	.20			2.37	.02
				.05[0-.10][a]			
BIS X BAS	.01	.001	.02			2.01	.05
				.074[0-.12][a]	0.024		

Note: Residual scores were used to create the interaction term. BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; MFT=Motivational Flanker Task.

[a]95% confidence interval

Table 9

Summary of alcohol misuse outcomes regressed on BIS and BAS Drive

Predictors	B	SE	Beta	R^2	R^2 change	t	p
			Alcohol-Related Problems (Criterion)				
BAS Drive	2.92	1.04	.22			2.8	.01
BIS residuals MFT	.02	.02	.08			.94	.35
				.06[0-.13][a]			
BIS X BAS Drive	.07	.04	.15			1.90	.06
				.08[0-.16][a]	.02		
			Average Weekly Alcohol Use (Criterion)				
BAS Drive	1.85	.70	.20			2.64	.01
BIS residuals MFT	.02	.01	.11			1.35	.18
				.065[0-.14][a]			
BIS X BAS Drive	.09	.02	.29			3.68	.001
				.15[.01-.19][a]	.085		

Note: BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; MFT=Motivational Flanker Task.

[a]95% confidence interval

Table 10

Summary of alcohol misuse outcomes regressed on BIS and BAS Fun Seeking

Predictors	*B*	*SE*	Beta	R^2	R^2 change	*t*	*p*
				Alcohol-Related Problems (Criterion)			
BAS Fun Seeking	5.52	1.15	.37			4.78	.001
BIS residuals MFT	.02	.02	.09			1.09	.27
				.15[.05-.25][a]			
BIS X BAS Fun Seeking	-.02	.04	-.04			-.52	.61
				.15[.05-.25][a]	<.001		
				Average Weekly Alcohol Use (Criterion)			
BAS Fun Seeking	2.68	.81	.26			3.31	.001
BIS residuals MFT	.02	.01	.12			1.57	.12
				.10[0-.16][a]			
BIS X BAS Fun Seeking	.06	.03	.18			2.34	.02
				.14[.01-.18][a]	.04		

Note: BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; MFT=Motivational Flanker Task.

[a]95% confidence interval

Table 11

Summary of alcohol misuse outcomes regressed on BIS and BAS Reward Responsivity

Predictors	*B*	*SE*	Beta	R^2	R^2 change	*t*	*p*
Alcohol-Related Problems (Criterion)							
BAS RR	5.52	1.15	.37			4.78	.001
BIS residuals MFT	.01	.03	.05			.54	.59
				.15[.05-.25][a]			
BIS X BAS RR	-.02	.04	-.05			-.52	.61
				.15[.05-.25][a]	.00		
Average Weekly Alcohol Use (Criterion)							
BAS RR	2.68	.81	.26			2.83	.005
BIS residuals MFT	.05	.02	.28			3.31	.001
				.11[0-.15][a]			
BIS X BAS RR	.06	.03	.23			2.34	.02
				.14[.01-.18][a]	.03		

Note: BAS=Behavioural Activation System; BIS=Behavioural Inhibition System; MFT=Motivational Flanker Task. RR= Reward Responsivity.

[a]95% confidence interval

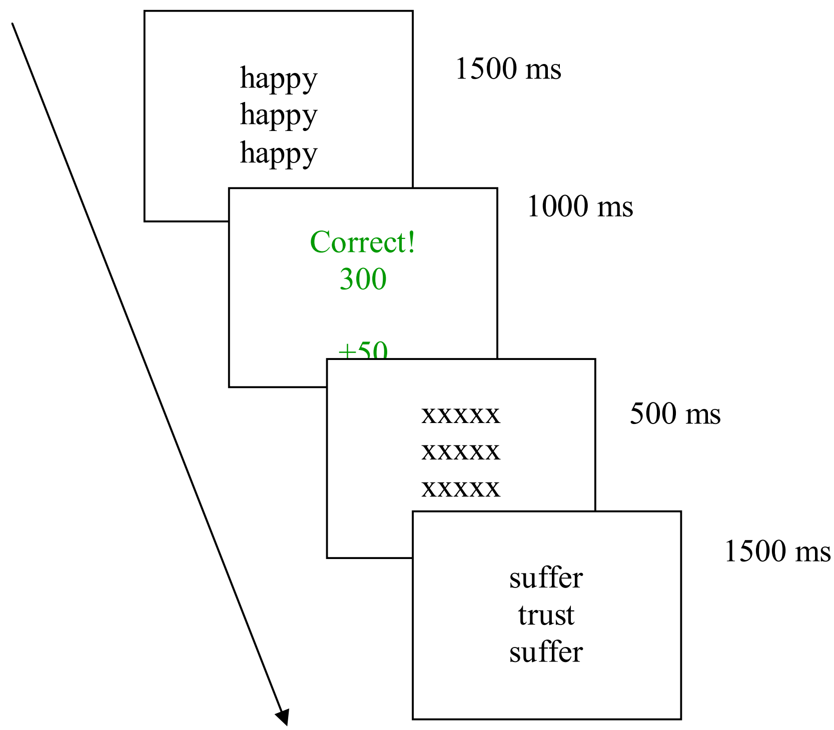
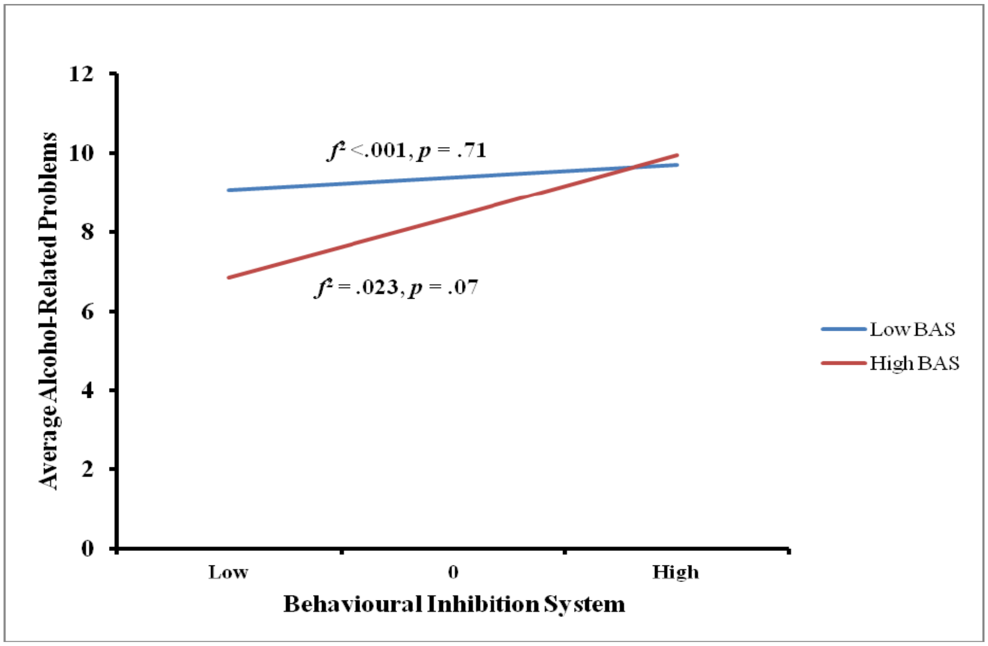


Figure 1. A schematic representation of one trial on the MFT.

Figure 2. Simple Slopes for Alcohol Misuse Outcomes regressed on BIS MFT Residuals at High and Low BAS MFT Residuals

a)



b)

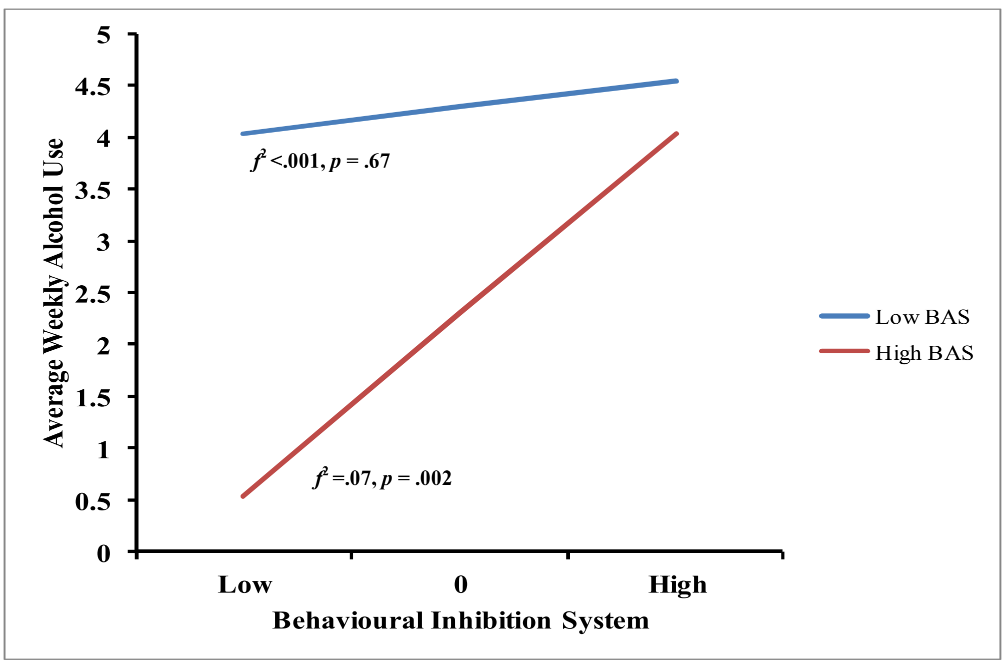
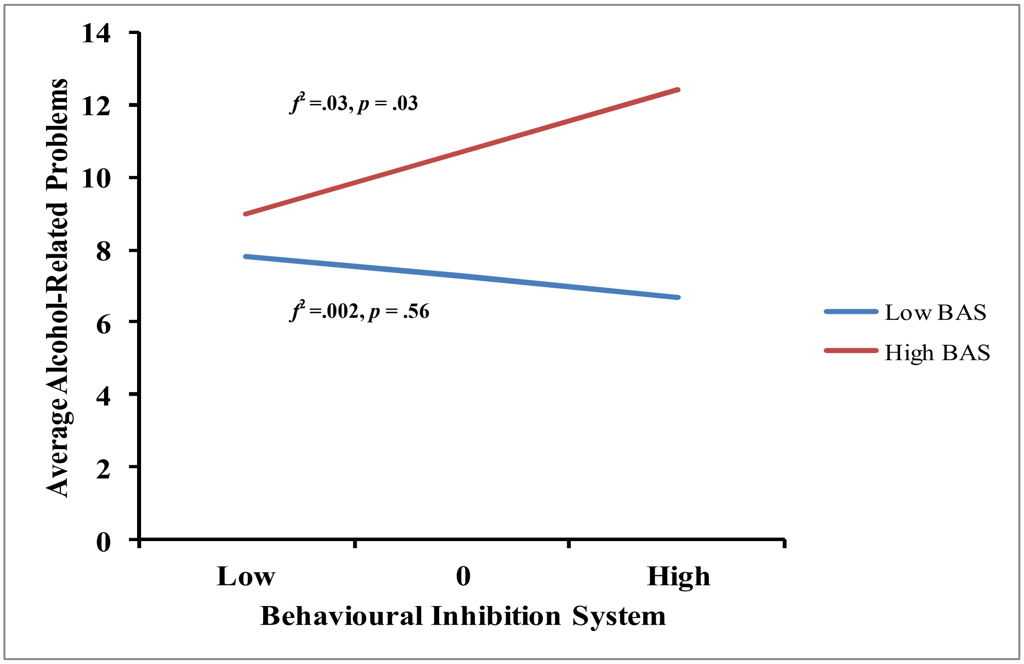


Figure 2: BIS and BAS were created by taking residual scores on the MFT. a) BIS by BAS interaction predicting average alcohol-related problems in the past year. b) BIS by BAS interaction predicting average weekly alcohol use in the past 30 days.

Figure 3. Simple Slopes for Alcohol Misuse Outcomes regressed on BIS MFT Residuals at High and Low BAS Drive

a)



b)

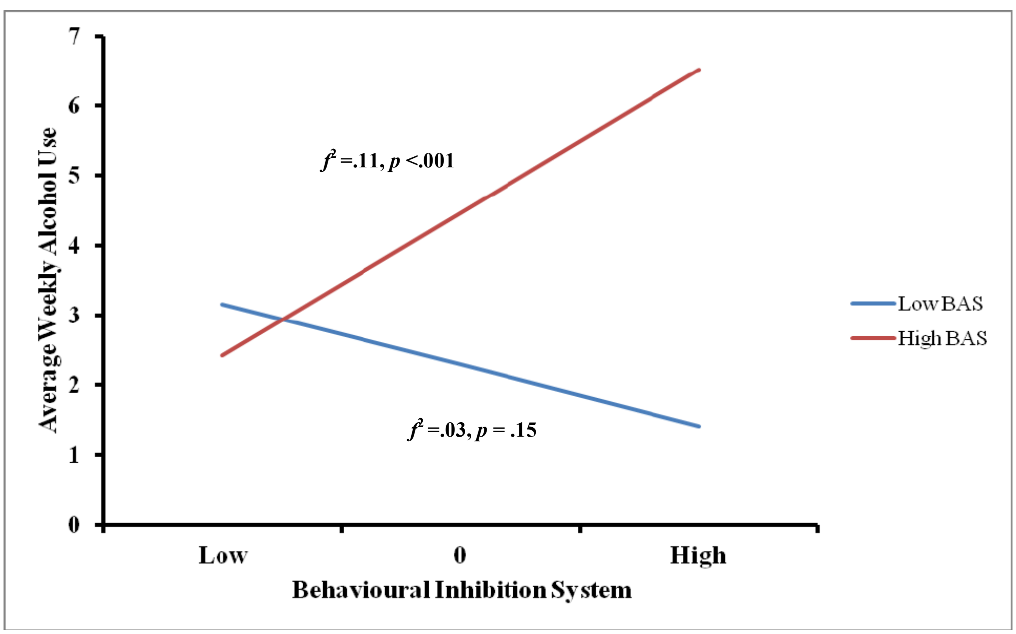
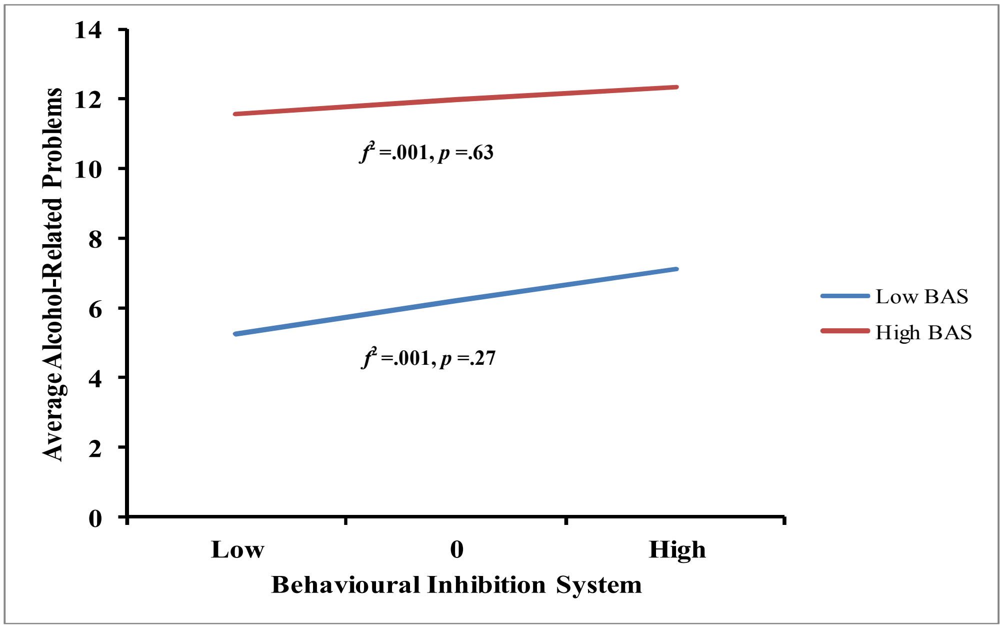


Figure 3: BIS was created by taking residual scores on the MFT and self-report BAS Drive was used. a) BIS by BAS interaction predicting average alcohol-related problems in the past year. b) BIS by BAS interaction predicting average weekly alcohol use in the past 30 days.

Figure 4. Simple Slopes for Alcohol Misuse Outcomes regressed on BIS MFT Residuals at High and Low BAS Fun Seeking

a)



b)

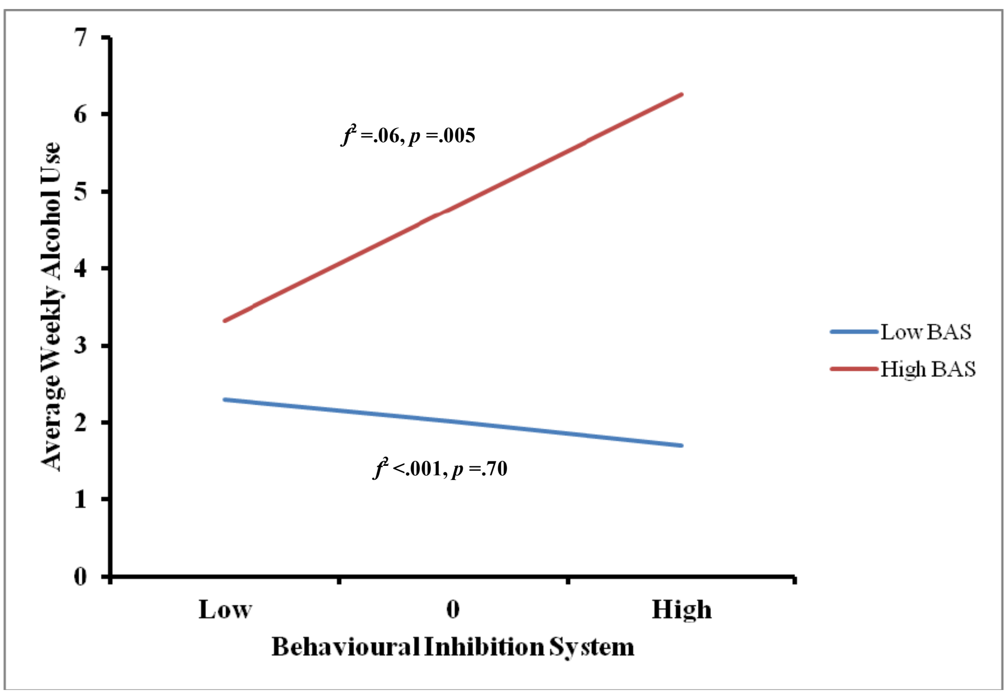
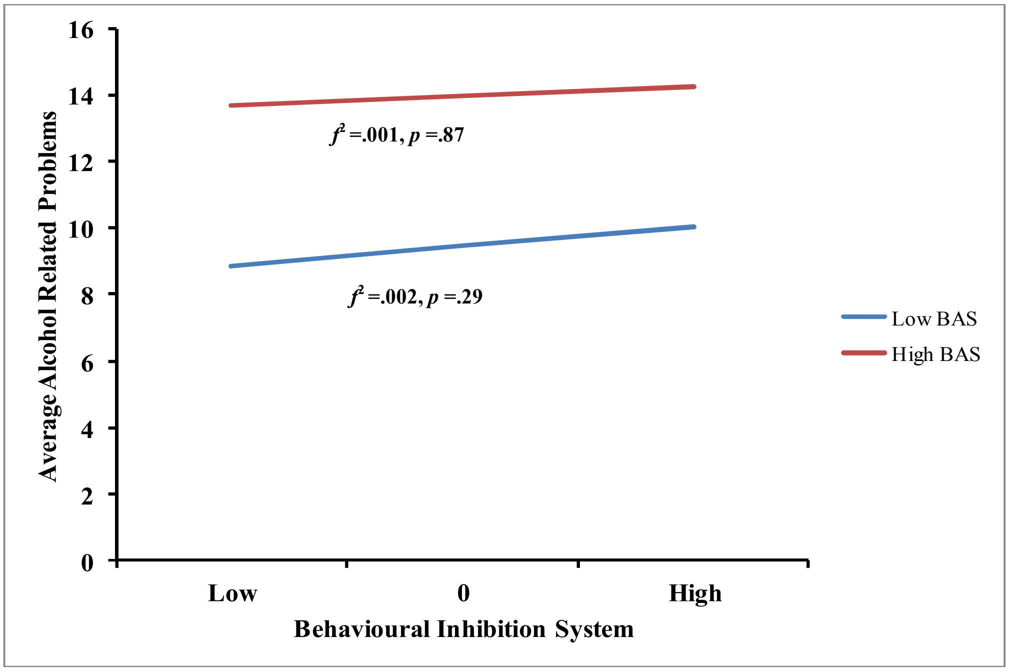


Figure 4: BIS was created by taking residual scores on the MFT and BAS Fun Seeking was used. a) BIS by BAS interaction predicting average alcohol-related problems in the past year. b) BIS by BAS interaction predicting average weekly alcohol use in the past 30 days.

Figure 5. Simple Slopes for Alcohol Misuse Outcomes regressed on BIS MFT Residuals at High and Low BAS Reward Responsivity

a)



b)

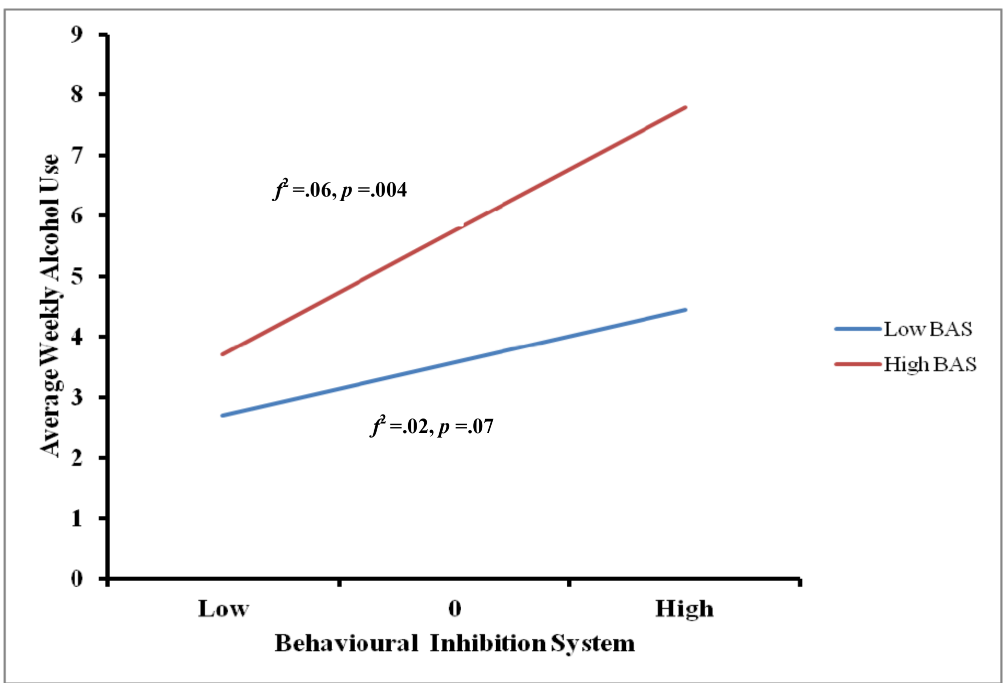


Figure 5: BIS was created by taking residual scores on the MFT and BAS Reward Responsivity was used. a) BIS by BAS interaction predicting average alcohol-related problems in the past year. b) BIS by BAS interaction predicting average weekly alcohol use in the past 30 days.

Appendix A

Exemplars of critical trial types in the MFT

Panel A

happy happy happy	fear fear fear	ticket ticket ticket

Panel B

suffer trust suffer	letter trust letter

Panel C

smile disease smile	house disease house

(A) On the far left is an example of a positive congruent trial type. In the middle is an example of a negative congruent trial type. On the far left is an example of a neutral baseline for each critical congruent trial type. (B) On the left is an example of a positive target, negative flanker incongruent trial. On the right is the corresponding control condition, where the target is positive, but the flankers are neutral words. (C) On the left is an example of a negative target, positive flanker incongruent trial. On the right is the corresponding control condition, where the target is negative, but the flankers are neutral words.

Appendix B

List of stimuli words used

Positive	**Negative**	**Neutral**
adorable	mistakes	magazine
funny	poor	pages
delight	disease	diary
humor	awful	house
smile	threat	ticket
laughter	difficult	dictionary
trust	fear	lift
pleasant	terrible	computer
exciting	afraid	library
happy	suffer	letter

Appendix C

Medians of Critical Trial Types on the MFT

	Critical Trial (ms)	Control Trial (ms)	*t*	*p*	*d*
Positive Congruent	638.25	642.02	-2.50	.05	-.18
Incongruent	665.01	652.74	1.99	.05	.15
Negative Congruent	672.54	642.02	9.24	.001	.44