COGNITIVE MODELING ANALYSIS OF PERFORMANCE ON THE IOWA GAMBLING TASK IN UNDERGRADUATES REPORTING SUBSTANCE USE

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This thesis entitled

COGNITIVE MODELING ANALYSIS OF PERFORMANCE ON THE IOWA GAMBLING TASK IN UNDERGRADUATES REPORTING SUBSTANCE USE

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Substance abusers display decision-making and executive functioning impairments, as measured by the Iowa Gambling Task (IGT) and Wisconsin Card Sorting Test (WCST), respectively. Reward-driven personality appears to be related to these constructs, and has also been shown to be higher in substance abusers. The current study examines decision making, executive functioning, and reward-driven personality characteristics of undergraduate substance users and controls. Decision-making performance (IGT) is separated into cognitive, motivational, and consistency processes. The present study finds that substance users perform significantly worse on IGT relative to controls, although no differences in the underlying cognitive or motivation processes exist. Substance users also perform significantly worse on WCST and display a more reward-driven personality. Thus, impaired decision-making and executive functioning and reward-driven personality are evident even in non-clinical substance users, suggesting these findings might be premorbid characteristics of substance users, not reflective of brain damage consequent to years of substance abuse.

Approved:

Julie Suhr

Associate Professor of Psychology
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Introduction

Substance abuse disorders are the leading cause of medical mortality, morbidity, and health expenditures in the United States (NCADD, 2002). A key component of substance abuse is the persistence of use for benefit of an immediate reward regardless of evidence that such action may have negative future consequences on family, career, and health (Bechara, 2003). This behavior is evident early in life, for over 40% of adult alcoholics experience some form of alcoholic symptomatology between the ages of 15 to 19 and at least 50% of individuals with substance disorders initiate drug consumption between the ages of 15 and 18 (Chambers, Taylor, & Potenza, 2003). The comorbidity of substance abuse with pathological gambling can be observed in up to 33% of drug and alcohol-dependent patients (Petry, 2000), thus the inability to attend to future consequences may be compounded with other impulsive activities to leave the individual extremely susceptible to harm. Individuals with substance abuse disorders commonly display decision-making impairments on gambling task paradigms, potentially linking substance abuse to ventromedial prefrontal cortex dysfunction based on similar performances between abusers and ventromedial patients on the Iowa Gambling Task (Bechara et al., 2001). Busemeyer and Stout (2002) have created a cognitive modeling analysis to examine the underlying motivational and cognitive processes for impaired performance on the Iowa Gambling Task, and have thus far carried out a handful of studies examining specific reasons for gambling task impairment in substance abusers.

Additional studies examining the relationship of gambling task performance to substance use are needed for several reasons. First, all gambling task and cognitive
modeling research in substance abusers has utilized clinical populations that are being tested after years of substance abuse. Neuroimaging studies suggest that a history of substance abuse (mean duration of 13 years) leads to a 5 - 11% decrease in frontal lobe gray matter (Franklin et al., 2002), causing a concern that observed decision-making impairments may reflect consequences of substance abuse rather than underlying predispositional behavioral patterns related to risk for substance abuse. Using an undergraduate substance using population in this line of research is a way to reduce the confound of abuse history while still tapping into heavy use/abuse behavior and risk for future substance abuse diagnosis. Additionally, while the model creation research has been replicated, only one published study has applied the modeling specifically to substance abusers (Stout et al., 2004).

The present study applied the cognitive modeling technique of Busemeyer and Stout to analysis of gambling task performance in undergraduates who report high rates of substance use, relative to non-using controls. In addition, the present study compared these groups in terms of self-reported personality characteristics and executive functioning performance. Prior to presenting the study, existing research on the relationships among the ventromedial and dorsolateral prefrontal cortices, executive dysfunction, and substance abuse decision-making impairments is reviewed, with particular attention to issues still not clearly addressed in the literature to date.

The Frontal Lobes and the Iowa Gambling Task

The frontal lobes are not homogenous entities but are divided into three functionally specialized sub-regions, namely the orbitofrontal, dorsolateral, and medial
Figure 1. Lateral (A) and medial (B) hemispheric views of the human brain, identifying the dorsolateral, medial frontal, and orbitofrontal prefrontal cortices.

Cummings & Mega, 2003

frontal cortices (Figure 1). All three regions are present in both left and right hemispheres. Few diseases affect only one region, therefore it is not uncommon for a syndrome to mix dysfunctions from multiple frontal regions (Cummings & Mega, 2003). The orbitofrontal region is characteristically associated with inhibition of impulses; patients with impairments to the orbitofrontal region will commonly display poor social judgment, impulsiveness, disinhibition and diminished self-supervision of behavior, tactlessness, and limited insight. The orbitofrontal cortex lies directly above the frontal eye fields at the most rostral and ventral portion of the prefrontal cortex and includes the ventromedial cortices. Major reciprocal connections to the amygdala, thalamus, hippocampus, and other prefrontal areas exist.

Alternatively, the dorsolateral prefrontal cortex mediates working memory and higher executive functioning. Lesions to the dorsolateral cortex can result in poor abstraction, reduced mental capacity and control, poor verbal fluency, impaired strategy
generation for solving complex problems, and difficulty altering strategies in response to changing contingencies (Cummings & Mega, 2003). The dorsolateral cortex is located above the orbitofrontal cortex in the most rostral and lateral sector of the prefrontal cortex and has reciprocal connections throughout the brain to coordinate affective, motor, and sensory information. Numerous neuropsychological tasks exist to detect impairment in this brain region, including the Wisconsin Card Sorting Test, the Stroop Color Word Test, and Delayed Match or Non-Match to Sample tasks.

Finally, the medial frontal region of the prefrontal cortex is the area associated with motivation and goal direction. Patients with medial frontal dysfunction will usually display apathy in affective, emotional, cognitive, and motoric dimensions (Cummings & Mega, 2003). They will also show decreased emotional concern, reduced interest and activity, or impaired initiation and task maintenance. The medial frontal region, including the dorsomedial prefrontal cortex, is located on the medial surface of each hemisphere surrounding the corpus callosum, and connects to both amygdalar and motor regions of the brain.

Historically, behavioral tests have readily identified individuals with damage to the dorsolateral frontal cortex, while individuals with ventromedial frontal damage and major behavioral changes have gone undetected on traditional “frontal lobe” measures. In the past twenty years, however, studies have identified specific impairment to the ventromedial prefrontal cortex leading to poor decision making, particularly with respect to immediate gains despite future negative consequences. Patients with lesions to the ventromedial cortex commonly develop severe impairments in personal and social
decision-making in spite of otherwise preserved intellectual functioning. As a group they characteristically begin to make choices that are against their best interests and do not appear to learn from past mistakes. Cognitive tasks developed to discern dysfunction in decision-making such as the “Gamble” and the “Risk” tasks (Rogers et al., 1999) and the Iowa Gambling Task (IGT; Bechara et al., 1994) are now often used in research on ventromedial dysfunction. Overall, in patients with ventromedial damage, these paradigms show that there appears to be a loss of importance placed on future consequences (Bechara, 2003).

The measure of decision-making currently receiving the most attention in the literature is the IGT. Originally created to detect poor decision-making in patients with lesions in the ventromedial prefrontal cortex, the IGT mimics real-life risk-taking situations in the way it involves uncertainty, reward, and punishment (Bechara et al., 1994). By requiring the user to choose between an immediate reward and a delayed, long-term punishment, the task assesses decision-making in a similar fashion to the normal self-promoting choices made daily. The IGT involves four decks of cards (A', B', C', D') and requires the subjects to make a series of 100 card selections in a sequential manner from any deck they choose. They receive $2000 credit to start the game and are instructed that the purpose of the task is to win as much money as possible. In order to do so, the subjects must learn to choose from the most advantageous decks. On every card selection, the subject is informed that they have won money, and on some selections they are also informed that they have lost money as well, depending on the deck selection and the location of the card in the deck. The payoff for each selection is higher for decks
A' and B' ($100) as compared to decks C' and D' ($50), but losses incurred while selecting from decks A' or B' will also be so much higher in value relative to decks C' or D' that choosing from A' or B' consistently will be disadvantageous (see Figure 2). Due to the higher monetary losses from decks A' and B', the subject on average will have a net loss of $250 after 10 card selections ($1000 gain minus $1250 in losses) from these decks, whereas 10 card selections from decks C' or D' would result on average in a net gain of $250 ($500 gain minus $250 in losses). It is therefore more advantageous to choose from decks C' and D' (Bechara et al., 1994).

Patients with ventromedial prefrontal cortex lesions commonly perform in an impaired fashion on the IGT (Bechara et al., 1994, 2000, 2001), which is consistent with research demonstrating the role of the ventromedial prefrontal cortex in judgment and
decision-making. In a compilation of multiple studies, the Damasio and Bechara laboratory has compared the performance of normal controls, patients with ventromedial prefrontal cortex lesions, and patients with dorsolateral prefrontal cortex lesions on the IGT. As the task progresses from the first to the 100th trial, normal controls gradually make more selections from the advantageous decks than from the disadvantageous ones. The patients with ventromedial lesions do not show improvement over trial selection, but rather persist in choosing from the bad decks (A’ and B’) throughout the duration of the task (Bechara et al., 1994). In contrast to other studies in the field (Parsons, 1975; Bechara et al., 2001), a study by Bechara et al. in 1998 showed that patients with dorsolateral lesions perform in a similar manner to the control subjects, in that their selection profile commonly involved selecting from each of the four decks until a large series of losses from the disadvantageous decks led them to prefer the advantageous ones (C’ and D’; Bechara et al., 1998). This study sampled from normal control subjects (n = 21), patients with bilateral ventromedial prefrontal cortex lesions (n = 9), and patients with either a left or right unilateral lesion to the dorsolateral prefrontal cortex (n = 10). From a neuropsychological perspective, it therefore appears that the ventromedial prefrontal cortex may be implicated in decision-making, and according to this study a unilateral lesion to the dorsolateral cortex is not sufficient to cause impairment on IGT performance.

Alternatively, Manes and colleagues examined both decision-making processes and executive functioning tasks in patients with lesions to different sectors of the prefrontal cortex and found that impairment in both the dorsolateral and the dorsomedial
prefrontal cortex is necessary to disrupt decision-making (Manes et al., 2002). Patients with discrete orbitofrontal/ventromedial lesions (n = 5), dorsolateral lesions (n = 4), dorsomedial lesions (n = 5), and large frontal lesions (n = 5) were compared to controls (n = 13) on the IGT, the “Gamble Task”, the “Risk Task”, as well as assessing recognition memory, working memory, planning ability, and attentional set-shifting. In the Gamble task, which was created specifically for their study, subjects must initially make a simple probabilistic decision and then gamble points based on the confidence of their decision (Rogers et al., 1999). A combination of 10 red and blue blocks is presented, and the participants must decide whether a yellow token is hidden under a red or blue block. The ratio of colored blocks varies randomly per trial to which the participant places bets based on their confidence in their decision being correct. Correct choices increase the total points by the amount bet and incorrect choices decrease the total points in a similar fashion. The Risk task (Rogers et al., 1999) is similar to the Gamble Task, except that there is a fixed bet available with each choice of box color and that these bets vary with the box color ratio across trials. A correct red choice will be worth a higher reward if the ratio of red to blue boxes is small, but the punishment will also be higher should that selection be incorrect. Manes found that patients with lesions in the dorsolateral and dorsomedial regions and the large lesion group selected more cards from disadvantageous decks than controls on the IGT. Meanwhile, the orbitofrontal group (containing those with ventromedial prefrontal cortex damage) did not perform in an impaired manner on the task. On the Gamble Task, the group with large frontal lesions placed higher bets than the other groups, and the combined
dorsolateral and dorsomedial lesion group deliberated for longer, but the overall scores for quality of decision making did not differ significantly between any of the groups. For the Risk Task, the large lesion group chose the more rare yet higher rewarding outcomes more often than controls (Manes et al., 2002).

According to Manes, it is the combined impairment in both the dorsolateral and the dorsomedial cortices that lead to dysfunctional decision-making. Manes’s results contrast a decade of empirical data from the Damasio and Bechara. The points of interest are that the large lesion group was impaired on all decision-making tasks and patients with dorsolateral lesions were impaired on the IGT, while the group composed of patients with lesions to the orbitofrontal cortex performed similarly to controls in all tasks. To reconcile differences particularly regarding the role of the orbitofrontal/ventromedial prefrontal cortex in decision-making, Manes offers multiple explanations. First, on the basis of the strict lesion group inclusion criteria, many of the patients used by Bechara et al. as ventromedial patients would actually be classified in the large lesion group in the Manes et al. study. In the Bechara et al. series, the medial orbitofrontal/ventromedial cortex represented only the area of lesion overlap between all of the patients. Secondly, in the Bechara et al. series, only patients exhibiting real-life decision-making deficits were included, as compared to all patients with ventromedial lesions. Finally, symptoms of depression were part of the exclusion criteria for the Manes et al. study while not for the Bechara et al. series. Decision-making deficits have been demonstrated in patients with mania and depression, therefore it is possible that mood disorder contributed to impairments in decision-making in Bechara and colleagues’ studies (Murphy et al., 2001).
Manes et al.’s study (2002) poses some questions regarding the validity of the highly established belief that the ventromedial prefrontal cortex is the sole neural region associated with decision-making. The results of this study have yet to be replicated, therefore one must be cautious in disregarding the role of the ventromedial cortex in decision making. However, based on the information in the Manes study and Bechara’s work, it can be deduced that both the ventromedial and dorsolateral prefrontal cortices are implicated in decision-making impairment.

Evidence of Impaired Decision-Making in Substance Abuse

There is empirical support to suggest that substance abuse is also linked to overall impairments in decision making, for numerous studies have investigated the mechanisms of decision making in substance abusers. Multiple strategies have been utilized, including the “Gamble” and the “Risk” tasks (Fishbein et al., 2004, 2005; Mazas, Finn, & Steinmetz, 2000; Rogers et al., 1999), with the most common paradigm for examining this relationship being the IGT. A myriad of studies have shown that substance abusing individuals perform worse on the IGT relative to controls, regardless of the drug of choice (see Table 1 for a review of these studies and their findings). Most substance-abusing participants had long-term durations of abuse and substantial histories of drug/alcohol rehabilitation. Even when controlling for age and education differences in the substance dependent/abusing groups relative to controls in many studies, decision-making impairment on the IGT was commonly observed.
Table 1
Substance Abuse and Iowa Gambling Task Performance: A Review of Studies

<table>
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<tr>
<th>Authors</th>
<th>Sample</th>
<th>Findings</th>
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<tr>
<td>Bechara &amp; Damasio, 2002</td>
<td>46 SD (15 day treatment min.); 10 VM; 49 CON</td>
<td>SD made less bad selections relative to VM but more bad choices relative to CON</td>
</tr>
<tr>
<td>Bechara, Dolan, &amp; Hindes, 2002</td>
<td>39 SD (15 day treatment min.); 10 VM; 31 CON</td>
<td>Subgroup of SD having lower net scores (good vs. bad) relative to CON</td>
</tr>
<tr>
<td>Bechara &amp; Martin, 2004</td>
<td>41 SD (15 day treatment min.); 39 CON</td>
<td>Lower net scores for SD relative to CON</td>
</tr>
<tr>
<td>Bechara et al., 2001</td>
<td>41 SD (15 day treatment min.); 5 VM; 40 CON</td>
<td>SD made less bad selections relative to VM but more bad choices relative to CON</td>
</tr>
<tr>
<td>Ernst et al., 2003</td>
<td>30 SD (48 hour tx center abstinence); 22 CON</td>
<td>SD made more disadvantageous deck selections in 3rd quintile relative to CON</td>
</tr>
<tr>
<td>Fein, Klein, &amp; Finn, 2004</td>
<td>44 abstinent alcoholics (6 month min.); 58 CON</td>
<td>Lower net scores for abstinent alcoholics relative to CON</td>
</tr>
<tr>
<td>Grant, Contoreggi, &amp; London, 2000</td>
<td>30 SD (48 hr tx center abstinence); 24 CON</td>
<td>Net scores lower for SD compared to CON</td>
</tr>
<tr>
<td>Petry, 2001</td>
<td>27 path. gamble SD (no tx requirement); 63 non-gambling SD; 21 CON</td>
<td>$37 lost for CON, $355 lost for non-path. gambling SD, $578 lost for path. gambling SD</td>
</tr>
<tr>
<td>Stout et al., 2004</td>
<td>12 cocaine abusers; 14 CON</td>
<td>Cocaine group selected fewer advantageous cards</td>
</tr>
<tr>
<td>Tucker, et al., 2004</td>
<td>17 cocaine dependents (5 day ave. abstinence)</td>
<td>Impaired performance linked to &gt; resting perfusion within ACG and frontal gyri</td>
</tr>
<tr>
<td>Whitlow et al., 2004</td>
<td>10 cannabis users (12 hr min abstinence); 10 CON</td>
<td>Cannabis users more impaired in blocks 3-5</td>
</tr>
<tr>
<td>Yechiam et al., 2005</td>
<td>82 SD (12 hour abstinence); 80 CON</td>
<td>SD made more risky selections in forgone payoff condition relative to CON</td>
</tr>
</tbody>
</table>

Note: SD = substance dependent individuals; VM = ventromedial prefrontal cortex lesioned patients; CON = controls.
Examining Bechara et al. (2001) as a representative study in the literature, substance abusers as a group select from the disadvantageous decks A’ and B’ at a higher rate than normal. In their study, three groups of subjects were tested on the IGT and compared: substance dependent individuals (n = 41), ventromedial prefrontal cortex lesioned patients (n = 5), and controls (n = 40). The ventromedial patients suffered a lesion at least 3 months prior to participation in the study and had bilateral involvement of the ventromedial cortices. Individuals in the substance dependent group were recruited while undergoing inpatient treatment for substance abuse; many were inpatients who had been admitted for detoxification and treatment, while others had recently completed substance abuse intervention but were returning periodically for testing. In addition, a small subgroup of substance dependent participants was a “success story,” returning for testing after a significant quantity of time being abstinent (Bechara et al., 2001, pp. 378). Due to the nature of recruitment, all individuals with substance abuse met DSM-IV criteria for substance dependence prior to or during hospitalization. The individuals with substance dependence had a mean abuse history of 10.9 years, and had been in treatment an average of 4.6 times. The drugs of choice were alcohol (17/41), cocaine/crack (14/41), and methamphetamine (10/41). All groups had approximately a 50% male population, while the substance group had significantly less years of education and was significantly younger than the control group. The results of the Bechara et al. study revealed a significant impairment in the performance of substance dependent individuals compared to normal controls. Over the 100 trials, controls increased their proportion of selections from advantageous decks at much faster rate and at a non-
impaired fashion compared to the ventromedial lesioned patients, who in general did not show an improvement in performance. A significantly high proportion ($\chi^2 = 6.6$, $p < 0.01$) of individuals with substance abuse performed within the impaired range of ventromedial patients, while the rest performed either similar to the unimpaired manner of the normal controls or within a range between the ventromedial patients and normal controls.

These results support a potential hypothesis that impairment in decision-making linked to a dysfunctional ventromedial cortex is associated with at least a sub-group of substance dependent individuals. This formation of two clusters of substance dependent performance (ventromedial-like and control-like) might possibly be explained by the researchers’ use of participants at varying stages of rehabilitation. It is possible that a prominent number of those in the subgroup performing in a similar manner to ventromedial patients were currently undergoing detoxification, while those described as a “success story” performed comparable to controls. If so, this would imply that patients who have not yet “kicked” their abuse of substances on average perform at an impaired manner and further strengthens the association between ventromedial dysfunction and substance abuse.

In addition to performance on decision-making paradigms, the association between substance abuse and the ventromedial prefrontal cortex can be seen in behavioral manifestations of high risk behavior as well as neuroimaging studies. As previously indicated, substance abusers and ventromedial patients show similar impairments on measures of decision-making, and both groups do not appear to be cognizant that a real-
life impairment of judgment is present (Bechara et al., 2001; Bechara, 2003). The poor performance on the IGT by substance abusers mimics the real-life behaviors of an individual with impairment in the ventromedial prefrontal cortex, for the substance abusing individual will consume a drug (high immediate reward) even though negative effects (long-term consequences) to career, family, or personal safety may be evident. These neuropsychological similarities suggest that the decision-making impairments connected with a dysfunctional ventromedial prefrontal cortex may be at the core of the problem of substance abuse (Bechara et al., 2001).

Similarly, with the application of functional neuroimaging techniques to substance abuse, substantial evidence has been shown that the ventromedial prefrontal cortex and its neural networks play a role in the behavior of substance abuse (London et al., 2000). The influence of the ventromedial prefrontal cortex and orbitofrontal cortex in the pathophysiology of drug dependence has been established (London et al., 2000) as well as supported by findings of lower resting orbitofrontal cortex regional cerebral blood flow in cocaine-dependent subjects and increased orbitofrontal activation in drug-dependent subjects after cue-induced craving or procaine infusion (Goldstein & Volkow, 2002; Adinoff et al., 2003). Other studies have further supported the link between substance abuse and a dysfunctional ventromedial/orbitofrontal cortex. Liu et al. (1998) indicated that polysubstance abusers have smaller frontal lobe grey matter volumes as compared to controls when examining the prefrontal cortex using magnetic resonance imaging, and drug abusers also exhibit differences in metabolic activity in the ventromedial prefrontal cortex when compared to matched controls (Volkow et al.,
In a final example, Grant et al. (1999) conducted PET assays on drug abusers while being tested on the gambling task. They concluded that the IGT performance was positively correlated with activation of the ventromedial cortex, meaning that the impaired performance observed in substance abusers was associated with a decrease in ventromedial activation.

Other Neuropsychological Deficits in Substance Abuse

Poor performance on the IGT is not the only deficit in functioning observed in individuals with substance abuse. Disturbances in executive functioning have also been observed, as illustrated by performances of substance abusers on the Wisconsin Card Sorting Test (WCST). The WCST involves higher order executive functioning related to choice and planning (Heaton, 1981), and requires the participant to utilize set shifting and abstraction ability in order to perform well. Briefly, the participant is presented with four sample cards on which to match some aspect of the 64 response cards (WCST-64 short form). The matching principles change during the task and the participants are required to adapt their matching strategy based on feedback from the examiner (Heaton, 1981). Functional neuroimaging studies support the role of the dorsolateral prefrontal cortex in performing this task (Berman et al., 1995; Fallgatter & Strik, 1998). Lombardi et al. (1999) used PET scans to determine that high perseverative responding had a strong association with right dorsolateral prefrontal cortex dysfunction. Multiple studies have shown that patients with lesions to their dorsolateral prefrontal cortex complete fewer categories and make greater numbers of perseverative errors on the task relative to controls (Grafman et al., 1990; Janowsky et al., 1989; Robinson et al., 1980). It has
therefore been claimed that the WCST is a fine tool for identifying dorsolateral prefrontal cortex impairment.

Recently the Damasio and Bechara laboratory examined the relationship between the dorsolateral prefrontal cortex and substance abuse. Along with testing substance abusers, ventromedial patients, and controls on the IGT in their 2001 study, Bechara et al. tested executive functioning among these groups using the WCST. Their results showed that the groups differed in performance on the WCST, with substance abusers making significantly more errors of perseveration than both ventromedial patients and controls. Although not significant, the mean number of categories completed was also lower for substance abusers compared to the other two groups, indicating a trend towards a deficiency in both measures of the executive functioning task. As described earlier, the mean age of the normal controls was found to be significantly higher than that of the substance dependent group, but not different from that of the ventromedial patients, whereas there were no significant differences in age between ventromedial patients and the substance dependent individuals. The difference in education mentioned above was significant between controls and individuals with substance dependence, but there were no other significant group differences in education. Both age and education level have been shown to be related to WCST performance, which may explain some of the variation in scores between substance dependent individuals and controls, but not between substance dependent individuals and ventromedial patients. Thus the effect of substance abuse on executive functioning resulting from this study remains substantiated.
Results from Bechara et al. (2001) linking poor performance on the WCST to substance abuse have predominantly been supported in the literature, although a few studies have contradicted these findings (see Table 2 for a review of relevant research). A later study from the same lab indicated a similar outcome to the 2001 study: individuals with substance abuse problems performed worse on the WCST than did control participants. In a study of 41 individuals with substance dependence and 37 controls, Bechara and Martin (2004) performed the IGT and a series of neuropsychological tests to assess basic cognitive functioning, including the WCST. Mean ages and education levels for the two groups were significantly different from one another (34.6 years old and 12.1 years of education for substance dependents compared to 29.4 years old and 15.0 years of education for controls). Alcohol, cocaine/crack and methamphetamine were the drugs of choice in the substance dependent group, who had a mean duration of abuse of 16 years. For the IGT, the substance dependent individuals performed significantly worse than controls. When splitting the 100 trials into 5 sets of quintiles, they found that controls had significantly higher scores than substance dependent individuals in the third, fourth, and fifth quintiles of selections. Most participants in the control group had a total score in the positive/advantageous range (a net score > +10), while most substance dependent individuals had scores falling below the cutoff of +10 for impairment. Meanwhile for the WCST, the study displayed a significantly greater number of perseverative errors by individuals with substance abuse while showing a mild deficit in the number of categories completed relative to controls (Bechara & Martin, 2004). These studies mimic the findings of many others (Table 2)
Table 2

Substance Abuse and Wisconsin Card Sorting Test Performance: A Review of Studies

<table>
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<td>46 SD (15 day treatment min.); 10 VM; 49 CON</td>
<td>More PE for SD as compared to VM or CON</td>
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<td>Bechara, Dolan, &amp; Hindes, 2002</td>
<td>39 SD (15 day treatment min.); 10 VM; 31 CON</td>
<td>More PE and fewer CAT for SD as compared to VM or CON</td>
</tr>
<tr>
<td>Bechara &amp; Martin, 2004</td>
<td>41 SD (15 day treatment min.); 39 CON</td>
<td>Greater PE and less CAT for SD relative to CON</td>
</tr>
<tr>
<td>Bechara et al., 2001</td>
<td>41 SD (15 day treatment min.); 5 VM; 40 CON</td>
<td>More PE for SD as compared to VM or CON; trend towards fewer CAT</td>
</tr>
<tr>
<td>Brokate, et al., 2003</td>
<td>25 KOR; 25 ALC (14 day min abstain); 24 CON</td>
<td>Fewer CAT, more errors and PE for ALC and KOR than CON</td>
</tr>
<tr>
<td>Ernst et al., 2003</td>
<td>Same adult data as in Grant et al., 2000</td>
<td>No significant difference b/w groups for CAT, PE, non-PE, failure to maintain set</td>
</tr>
<tr>
<td>Grant, Contoreggi, &amp; London, 2000</td>
<td>30 SD (48 hour tx center abstinence); 24 CON</td>
<td>No significant difference b/w groups for CAT, PE, non-PE, failure to maintain set</td>
</tr>
<tr>
<td>Hoff et al., 199</td>
<td>38 cocaine abusers (3 month tx min.); 54 CON</td>
<td>Greater number of total errors, PE, and CAT for cocaine abusers</td>
</tr>
<tr>
<td>Leng &amp; Parkin, 1988</td>
<td>7 KOR; 5 post encephalitic; CON</td>
<td>KOR achieved fewer CAT and more total errors than CON and encephal.</td>
</tr>
<tr>
<td>Rosselli et al., 2001</td>
<td>42 cocaine abusers (2 month tx min.); 17 CON</td>
<td>Fewer CAT for cocaine group, less total errors</td>
</tr>
<tr>
<td>Shoqeirat, et al., 1990</td>
<td>16 KOR; 10 encephal; 5 ACoAAs; 31 CON</td>
<td>KOR alcoholics impaired on CAT, PE, and total errors</td>
</tr>
<tr>
<td>Sullivan, et al., 1993</td>
<td>22 ALC (3 week treatment min.); 22 SZ; 7 FL; 16 CON</td>
<td>ALC had more failures to maintain set and less CAT relative to all other groups</td>
</tr>
</tbody>
</table>

Note: SD = substance dependent individuals; VM = ventromedial prefrontal cortex lesioned patients; FL = frontal lobe patients; SZ = schizophrenic patients; KOR = Korsakoff’s patients; ALC = alcoholic patients; CON = controls; ACoAA: Anterior Communicating Artery Amnesic patients; PE = perseverative errors; CAT = categories completed.
who showed that perseveration is a characteristic of alcoholics and drug abusers on the WCST.

Alternatively, the laboratory of Grant and colleagues has found that substance abusers do not perform in a significantly different fashion to controls on the WCST, although non-significant trends hint that substance abusers may be more impaired (Grant et al., 2000). The study utilized drug users (n = 30) and controls (n = 24) on both the IGT and WCST tasks, whom as groups had significantly different ages, IQs, and years of education. As a group the drug users were older, less educated, and possessed lower IQs relative to controls. The selection process for participants in the substance abuse group was that members had to provide evidence on interview/questionnaires as having a history of opioid or stimulant use, as well as testing positive for the either the presence of drugs or their metabolites in the bloodstream at the time of admission into the study. Among the sample, the average duration of abuse was 7.6 years for cocaine, 6.8 years for heroin, 13.8 years for marijuana, and 15.1 years for alcohol. In accord with the established research, substance abusers in their study made more deck selections from the disadvantageous decks on the IGT. However, drug abusers did not perform significantly worse on any of the possible variables of the WCST (categories completed, perseverative errors, nonperseverative errors, failure to maintain set) relative to controls, even though the trend for each variable was in the direction of more impaired performance.

The cursory review has shown that the overwhelming evidence leans towards findings of impairment on the WCST by substance abusers. Of the twelve studies examined in Table 2, ten show group differences between substance abusers and controls
for various WCST variables, and one shows non-significant trends towards substance abuse impairment. Combining this information with both empirical neuropsychological and neuroimaging data linking the WCST with the dorsolateral prefrontal cortex, it appears that the dorsolateral cortex may also have a role in the executive functioning deficits possessed by substance abusers. When taken together with the performance impairments on the IGT in substance abusers, this greatly links both the dorsolateral and ventromedial prefrontal cortex to problems with substance abuse.

Personality Characteristics Associated with Substance Abuse

Substance abuse has also been linked to specific personality characteristics. For example, due to the high co-morbidity between substance abuse and pathological gambling, an underlying personality trait such as impulsivity may be at the core of these behaviors (Petry, 2001). Numerous studies have shown substance abusers scoring higher on impulsivity measures than controls (Patton et al., 1995; Petry, 2001; Tcheremissine et al., 2003). The Go/No Go task is a measure of impulsivity and response inhibition; participants are required to respond to a stimulus or inhibit their response when exposed to the same stimulus as appropriate. Horn et al. (2003) performed a fMRI activation study for the Go/No Go task in normal adult males as well as examined the relationship between the task and both the Eysenck’s and Barratt’s Impulsivity Scales. Their results indicated that neural responses during response inhibition were greatest in the right lateral anterior orbitofrontal cortex, and that the task was associated with the self-report measures of impulsivity. These findings are consistent with evidence that medial prefrontal lesions result in poor impulse control (Horn et al., 2003), a personality trait
commonly observed in substance abusers. Additionally, the neurological regions implicated in the Go/No Go task are the same as a core brain region involved in substance abuse (orbitofrontal cortex), thus the Go/No Go task may be a good measure to tap discrepancies of impulsivity and response inhibition in substance users relative to controls.

Gray (1972, 1990) theorized that impulsivity and anxiety comprise the two fundamental dimensions of personality. These qualities of personality represent individual differences in the sensitivity of two neurological systems in their response to environmental cues: the Behavioral Inhibition System (BIS) and the Behavioral Activation System (BAS). BIS is sensitive to signals of punishment, non-reward, and novelty, and limits behavior that can eventually lead to negative consequences (Carver & White, 1994). Alternatively, BAS is sensitive to signals of reward, non-punishment, and escape from negative experiences and can lead to the achievement of goals or other reward-driven behaviors. According to this theory, substance abuse can be considered an overpowering of the BAS system with respect to the BIS, because the behavioral benefits achieved by the drug (reward) are more highly weighted than the negative consequences of abuse (punishment).

Van Honk (2002) separated undergraduates into groups based on extreme BIS/BAS scores and compared their performance on the IGT. The results were consistent with Gray’s theory, for the BIS dominant individuals performed normally on the task whereas the BAS dominant subjects performed in a more impaired manner. It would be expected that a reward-based temperament (BAS) would be driven by the high
immediate rewards regardless of the consequences, whereas the anxiety/punishment driven temperament (BIS) would be prone to avoid the large long-term penalties and would therefore select primarily from the more advantageous decks.

In sum, it has been shown that individuals with substance abuse problems are impaired on decision making (IGT) and executive functioning tasks (WCST), both of which are associated with the prefrontal cortex (ventromedial and dorsolateral). These individuals also score highly on the BIS/BAS reward temperament questionnaire and are related to another personality characteristic (impulse control), which in controls is also associated with IGT impairment and prefrontal dysfunction. Additionally, imaging studies have linked substance abuse to deficits in frontal lobe functioning. When taken together, evidence from these multiple sources suggests that substance abuse, decision making, executive functioning, impulse control, and reward drive are all related constructs and are associated with similar sub-regions in the frontal lobes.

Limitations to Existing Decision-Making/Substance Abuse Literature

Despite the large contributions to this field of study, there are some limitations with the existing literature that still leave questions unresolved. First, the IGT is a complex cognitive task, and the overall score does not parcel out decision-making impairment into its more specific components. The only laboratory that successfully examined the processes involved in decision making on the IGT has done so a minimal number of times. Secondly, the utilization of clinical substance abusing populations in most decision-making studies complicates the question of causality between substance abuse and impaired decision making since chronic abuse is linked to brain damage.
Finally, few studies in the literature have controlled for affect when examining decision-making performance, which can influence levels of risk-taking and aversion.

_Decomposing the IGT_

There are limitations to the knowledge that performance on the IGT may provide using the research methodologies conducted thus far. Although a vast body of knowledge has been accumulated in reference to which population groups display impaired performance on the IGT, the principle explanation for a group’s particular level of impairment in decision making has been difficult to elucidate. In response to this deficiency, Busemeyer and Stout (2002) created a modeling analysis to identify the cognitive process underlying poor performance on the IGT. The researchers point out that poor performance on the task may occur for a multitude of reasons, and after a series of experiments have streamlined their modeling into three distinct categories of explanations: motivational significance of reward (wins vs. losses), poor memory or ignorance of prior outcomes, and impulsivity or randomness of selections (Busemeyer & Stout, 2002; Stout et al., 2004). The expectancy valence model, as it is called, is composed of a mathematical parameter for each category: the weight given to losses relative to gains (affective valence), the update parameter determining the relative influence of the new experience on the expectancies, and the consistency that the IGT participant applies the expectancies when making a decision (sensitivity parameter), respectively. For instance, a poor IGT performance could be the result of an over-emphasis on wins or losses, an inability to remember or intentionally ignore previous negative outcomes, or a general erratic style of decision making (Stout et al., 2004).
model therefore provides a theoretical framework for the comparison between the
cognitive versus the motivational processes involved with high-risk decision making.

The development of the expectancy valence model came about by comparing the
modeling paradigm with competing models also grounded in support from the decision-
making literature, namely the strategy-switching heuristic choice model and the
Bayesian-expected utility model. The strategy-switching model is based on the approach
that people make decisions based on simple heuristic strategies, and they learn to adapt or
switch strategies with respect to the decision environment and task demands. Initially
assuming that high immediate payoffs are most advantageous, this model suggests that
decision makers will choose from the disadvantageous decks during the initial winning
stage until reaching the point of large losses. From that point, the decision maker will
switch hypotheses and choose from the more advantageous decks (Busemeyer & Stout,
2002). Alternatively, the Bayesian-expected utility model approaches decision making
with the notion that people attempt to optimize their decisions under constraints imposed
by human information processing limitations. The expected utility per deck is
recalculated on each trial based on the previous outcome, so that the deck that maximizes
the expected utility is chosen on each trial (Busemeyer & Stout, 2002). The three models
were applied to IGT performance by individuals with Huntington’s disease (n = 14),
individuals with Parkinson’s disease (n = 20), and healthy controls (n = 33). The average
age of the Huntington’s patients (44.6 years) was less than that of Parkinson’s patients
(66.0 years) and healthy controls (56.8 years). The healthy controls and Parkinson’s
disease patients learned to prefer selections from the advantageous decks over the course
of the 100 trials, but the Huntington’s disease group actually decreased their tendency to choose from the advantageous decks, thus performing in a more impaired manner. Following the task, the best fitting model between the three was selected and used to provide the basis for the estimation of parameters and their interpretations. All three models were compared to a baseline model to determine the mean improvement in using the particular model \( G^2 = 2[L_{\text{cognitive}} - L_{\text{baseline}}] \), where L is synonymous to the fit of the model. For all three population groups, the expectancy valence model outperformed the baseline model, while the strategy-switching and Bayesian-expected utility models generally did no different than the baseline model. The expectancy valence model produced larger \( G^2 \) values (improvement) than the strategy-switching model for 76% of the participants and larger \( G^2 \) values than the Bayesian-expected utility model for 85% of the participants (Busemeyer & Stout, 2002). Overall it was clear that the expectancy valence model was superior to the other two models.

Such modeling has been influential in determining the explanations for why substance abusers typically perform at an impaired level on the gambling task. Stout et al. (2004) applied the expectancy valence modeling analysis to the IGT performance of male cocaine abusers \((n = 12)\) and controls \((n = 14)\). The cocaine group was significantly older \((36.9 \text{ vs. } 30.0 \text{ years old})\) and had lower IQ scores \((93.7 \text{ vs. } 105.0)\). Stout found that not only did the drug users perform worse on the task than controls, but differences existed in the magnitudes of the modeling parameters between groups. The results indicated that there were group effects on the motivational and sensitivity parameters, but not on updating rate. The loss weight parameter was significantly lower for the cocaine-
abuse group than for controls, meaning that the drug abuse group was either less
influenced on their card selections by losses or more influenced by gains in comparison.
Also, the sensitivity parameter for the cocaine group was significantly smaller than that
for the control group, meaning that their card selections were less consistently related to
their expectancies. Alternatively, the lack of significance for updating rate indicates that
cocaine abusers were not suffering from an inability to remember past selections from
disadvantageous decks. As a quality-control check, Stout et al. (2004) used the
expectancy valence model to predict which scores belonged to a group and found that all
of the drug abuse participants were correctly classified (12/12), and 11 of the 14 controls
were appropriately identified by their group (89% accuracy). This study lends credence
to the belief that the expectancy valence model is a reasonable measure to explain poor
decision making in individuals with substance abuse.

As mentioned previously, while their cognitive model appears to be ideal for
examining the underlying cognitive processes involving decision-making impairment,
more research needs to be performed. No other laboratories have examined the
expectancy valence model on the IGT, especially in substance abusing populations. The
Busemeyer laboratory has supported the use of the model for the general population, but
further replications on substance using/abusing populations are necessary to add more
validation for its applicability to this group.

Sample Limitations

An additional limitation in the study of decision-making impairments in substance
abusers is that most research uses clinical populations of substance abusers who by
definition have a long history of abuse. It is well documented that substance abuse is related to brain damage. MRI studies have shown that frontal lobe volume losses have been identified in cocaine-, alcohol-, marijuana-, and heroin-dependent individuals (Liu et al., 1998; Franklin, et al., 2002; Pfefferbaum et al., 1997). For cocaine- and heroin-dependence in particular, negative correlations between prefrontal volume and years of abuse have been observed, which imply a cumulative effect of substance abuse on frontal lobe volumes (Liu et al., 1998). This suggests that the process of neurodegeneration caused by substance abuse is a continuous one, with the damage becoming more extensive as the duration of abuse increases. A difficulty therefore lies in deducing whether poor decision-making abilities of substance abusers are the cause of or the result of substance abusing behavior in clinical populations, for their long abuse history confuses any simple explanation.

The fundamental supposition for the current research is that substance abuse and poor decision-making abilities are associated constructs connected by some underlying biological or personality trait. In other words, certain personality/tempermental characteristics may increase the likelihood of a person engaging in high risk behaviors and also be related to general decision-making impairment. Blum et al. (1996) has proposed the “Reward Deficiency Syndrome” to explain the connection, stating that the biological substrates of reward that underlie the addiction to alcohol and other drugs are also the basis for impulsive, compulsive, and addictive disorders comprising the reward deficiency syndrome. A dysregulation in the chemistry that alters the intercellular signaling in the brain’s reward process could exchange an individual’s feeling of well-
being with anxiety, anger, or a craving of a substance that can alleviate the negative emotions. Blum further states that it is this chemical imbalance, involving the dopamine D2 receptor, which manifests itself as one or more behavioral disorders comprising the reward deficiency syndrome.

Using molecular genetics to isolate the individual receptor subunits, it has been determined that Chromosome 11 contains the A1 allele of the D2 receptor that has been identified as a possible link to alcoholism (Blum et al., 1996). Of the four D2 alleles known (A1-4), the A2 allele is present in nearly 75% of the general population whereas the A1 occurs in only 25%. In a study in 1990, Blum et al. found that in a sample of 35 alcoholics, 69% had the A1 allele while only 31% had the A2 allele, meanwhile the non-alcoholics had similar results as the general population. This increase in the prevalence of the A1 allele may be affecting the dopaminergically driven reward pathways in alcoholics, leading to the increased need to achieve satisfaction via drinking. In fact, a high prevalence of the A1 allele has been associated with a 30% reduction in dopamine D2 receptors, which will lead to decreased dopaminergic activity in those areas involved in reward such as the nucleus accumbens, globus pallidus, and hippocampus (Blum et al., 1996). With the prefrontal cortex being a central component to this alcohol reward pathway (craving, binging; Goldstein & Volkow, 2002), the implications for the connections between decision making and substance abuse become even stronger. Over several years, 14 independent laboratories have supported the finding that the A1 allele is a risk factor in severe forms of alcoholism (Blum & Noble, 1994). While not proving that the A1 allele of the dopamine D2 receptor is the only cause of severe alcoholism,
these results are strong indicators that the A1 allele has a significant role. Similarly, a
survey by the National Institute of Drug Abuse showed that the A1 allele is also
associated with polysubstance dependence (Uhl et al., 1993). In addition, other disorders
under Blum’s proposed Reward Deficiency Syndrome rubric also display heightened
levels of A1 allele dopamine D2 receptor prevalence: Forty-eight percent of smokers
(Noble et al., 1994), 45% of compulsive binge eaters (Noble et al., 1994), and 51% of
pathological gamblers carry the A1 allele (Comings et al., 1996). Also, 49% of children
with attention-deficit hyperactivity disorder and 45% of people diagnosed with Tourette’s
disorder have the allele of interest (Comings et al., 1991). As indicated above, there is
clearly a biological component to the underlying associations between these behavioral
disorders, all of which can have a physical manifestation involving risky or impulsive
personality traits. With the pervasiveness of impulsivity throughout the range of
disorders in Blum’s rubric, it should not be surprising that impulsivity or high riskiness
are such core risk factors for the relationship between substance abuse and poor decision
making.

By avoiding the use of chronic substance abusers who may possess substance-
related frontal lobe damage proportionate to their years of abuse, the proposed study
hoped to diminish long-term substance use as a confound and be able to examine the
relationship between decision making, personality characteristics and substance use more
clearly. Instead, undergraduate substance users were utilized at an age when substance
abusing behavior is present but neurodegeneration is likely not as extensive. The use of
such an age group in examining substance use/abuse is valid, for as indicated in the
opening paragraph of the introduction, clinically defined substance abusing behavior is evident early in life. The fact that almost half of alcoholics and substance abusers experience symptoms of abuse between the ages of 15 to 19 (Chambers, Taylor, & Potenza, 2003) is a good example of the relationship between teenage and life-long abuse.

While it is clear that not all teenagers and undergraduates who consume alcohol or drugs become chronic abusers, longitudinal evidence shows that taking part in such activities greatly increases the likelihood of facing severe substance abuse problems in later adulthood. In a nationally representative longitudinal study of 7541 participants spanning 17 years (18 to 35 years of age), when compared to those who abstained from alcohol as 18 year olds, it was found that participants who drank heavily were 3 times more likely to become alcoholics in later life (Merline et al., 2004). Similarly, compared to those participants abstaining from marijuana and any other illicit drugs at 18 years old, individuals who had tried the aforementioned drugs in their teens were 8 and 5 times more likely to use/abuse marijuana and cocaine in later life, respectively (Merline et al., 2004). Other longitudinal studies in both the United States and internationally have found analogous results (Chou & Pickering, 1992; Stenbacka, 2003). In Sweden, longitudinal data from 7577 conscripts showed that 18 year olds experiencing alcohol or drug abuse were 3 and 6 times more likely to become problematic alcohol or drug abusers 27 years later, respectively (Stenbacka, 2003).

In essence, by utilizing undergraduate reported high use of substances, it was hoped that individuals with a high risk for current and/or future substance abuse problems
were identified, prior to experiencing significant neurodegeneration related to substance use/abuse. As indicated by Blum’s “reward deficiency syndrome” hypothesis (Blum et al., 1996), it is the presence of underlying biological and presenting personality traits that lead to this reward-seeking behavior (substance use/abuse) and resultant deficits in decision-making capacity; thus the personality traits and decision-making impairments of substance abusers would appear to be wired in at an early age and should therefore be present as an undergraduate prior to the chronically abusive state.

*Control for Affect*

A final limitation to the literature regarding the gambling task is that affect is often not controlled, even though changes in mood could clearly alter performance on a decision-making/risk-taking task such as the IGT. Prior to Manes et al. in 2002, previous decision-making studies had not reported psychiatric status or had the diagnosis of depression as part of the exclusionary criteria, which means that they may consequently be confounded by affective effects. Murphy et al. (2001) have demonstrated that patients suffering from primary mania and depression revealed decision-making deficits on the Gamble Task. Arkes, Herren, and Isen (1988) have shown that a positively induced mood is associated with more conservative gambling strategies, and Nygren (1998) has similarly found that participants whose mood had been positively induced were more risk aversive than those whose mood was negatively induced. The Positive and Negative Affect Schedule (PANAS) is a valid measure of mood (Watson, Clark, & Tellegen, 1988). The two factors assessed in the scale are positive and negative affect, which represent overall affective state dimensions. By
measuring the level of affect of participants prior to their completion of the IGT, the present study controlled for level of affective influence on gambling task performance.

Present Study

The current study attempted to explain substance use in terms of both personality and decision-making processes. The strategy was to use cognitive modeling to break down expected impairment on the Iowa Gambling Task into the motivational, cognitive, and impulsive process explanations within an undergraduate substance-using population via an existing dataset, accounting for the effects of state affect on gambling task performance. Based on Liu et al.’s results (1998) that substance-related frontal lobe damage appears to increase with increasing years of abuse, most substance abusers (at this stage of development) would have already displayed substance dependent symptomatology without yet experiencing an extreme magnitude of neural damage as a result of substance use. Therefore it may be easier to elucidate the actual relationship between decision-making impairment and substance use in this high risk population. Traditionally, substance abuse is not considered a dispositional variable throughout the population (Power et al., 2005), so grouping the participants into substance users and controls fits this convention.

Similar to the results in the Stout et al. study (2004), substance users were expected to display impaired performance on the IGT, while placing more emphasis on losses or gains and making card selections in a more erratic manner. Therefore the first two hypotheses were that substance users would perform worse specifically on the third, fourth, and fifth quintiles of the IGT than controls, and they would have significantly
smaller parameters for loss weight and sensitivity relative to controls, but not for the updating parameter.

Additional objectives of the study were to examine differences in substance using undergraduates with respect to executive functioning and personality measures that appear to be linked to the frontal lobe. Due to the preponderance of evidence supporting impairment on the Wisconsin Card Sorting Test by substance abusers (see Table 2), it was proposed that the substance-using group would perform in an more impaired manner than controls on the WCST variables of Failure to Maintain Set, number of categories completed, and number of perseverative errors. Also, high scores on the BIS/BAS reward scale indicate a heightened preference for rewards (Carver & White, 1994); therefore a fourth hypothesis was that substance users would score higher than controls on this scale. Furthermore, increased scores on the Go/No Go task are a measure of elevated level of impulsivity or decreased response inhibition (Horn et al., 2003). Due to the impulsive nature of substance abuse and similarities in neuroactivation between impulse control and substance abuse (orbitofrontal cortex; Petry, 2001), the fifth hypothesis was that substance users would obtain higher numbers of errors on the Go/No Go task relative to controls.

Methods

Observations

Data for the study came from an archival dataset. From a previous study (Tsanadis, unpublished work), 91 participants were recruited from the Ohio University undergraduate population. The study lasted approximately 1.5 hours per participant, for
which each received 2 credits for his/her participation. The experiment was advertised on the OU experimental psychology pool from the first summer session to the fall quarter of 2004 for undergraduates required to attain research credits for psychology courses taken concurrently. Participants with a history of serious head injury or concussion, Learning Disorder or Attention Deficit Hyperactivity Disorder, other neurological history (seizures, brain tumor), or current psychological counseling were excluded from the original data collection. For the proposed study, based on effect sizes derived from the substance abuse/gambling task literature (Cohen’s d = -3.19 for IGT total performance in Grant et al., 2000; d = .67 and d = 1.23 for the expectancy and sensitivity parameters in Stout et al., 2004, respectively) and the number of potential participants in the existing dataset, a sample size of 56 (28 per group) would result in a power estimate of at least .80 when using a one-tailed alpha of .05. To be conservative, an independent samples t-test was used in the analysis with the sensitivity parameter of effect size d = .67.

Measures of Interest to the Present Study

While additional measures were used in the original study, only the measures of interest to the present study will be discussed in detail.

*Cognitive Appraisals of Risky Events- Expected Involvement (CARE-EI)*

The Cognitive Appraisals of Risky Events (CARE; Fromme et al., 1997) self-report questionnaire was used to place participants into substance use groups for analysis of the study’s hypotheses. The CARE was created to measure expected risk of, expected benefit from, and expected involvement in risk-taking activities in an undergraduate population. The measure is composed of six factor-analytically derived subscales for
risk-taking behavior, which tap into individual facets of risk-taking behavior including 1) Illicit Drug Use, 2) Aggressive and Illegal Behaviors, 3) Risky Sexual Activities, 4) Heavy Drinking, 5) High Risk Sports, and 6) Academic/Work Behaviors (Fromme et al., 1997). A total of 30 questions are on the questionnaire; each question utilizes a 7-point Likert response scale ranging from 1 = not at all likely to 7 = extremely likely. In general, the CARE has an adequate internal consistency, with Cronbach’s alphas for the Expected Involvement subscales (which were used in the prior study) as follows: Illicit Drug Use subscale was $\alpha = .81$, Aggressive and Illegal Behaviors was $\alpha = .85$, the Risky Sexual Activities subscale had an $\alpha = .78$, the Heavy Drinking subscale was $\alpha = .83$, High Risk Sports had an $\alpha = .64$, and Academic/Work Behaviors was $\alpha = .86$ (Fromme et al., 1997). There was no Cronbach’s alpha reported for the overall questionnaire. In addition, the test-retest reliability was not examined by Fromme for the Expected Involvement (EI) scale, because “the temporal element of the instructions (i.e., expected involvement during the next 6 months) would attenuate results” (Fromme et al., 1997, pp. 432). In terms of convergent validity, CARE-EI scores were significantly (positively) correlated with Impulsive Unsocialized Sensation Seeking (IMPUSS) scores and significantly (negatively) correlated with Social Conformity Questionnaire (SCQ) scores. A similar pattern of relationships were seen for the Expected Benefit and Frequency of Involvement CARE ratings. Thus the CARE-EI displayed strong convergent validity with known measures of trait risky behavior and sensation seeking (Fromme et al., 1997).

In the archival dataset, participants rated their expected involvement of risky behavior based on the likelihood of engaging in each activity during the subsequent 6
months. The purpose of inquiring about substance involvement six months in the future was the expectation of more honest reporting of illegal behaviors as compared to the reporting of current participation in illegal activities. For the present study, participants were categorized into high-risk and control groups for heavy drinking and drug use based on the results from the Heavy Drinking and Illicit Drug Use subscales of the CARE-EI. Those participants who scored in the highest third of the combined illicit drug use and heavy drinking subscales for their gender were in the high-risk substance using group and those participants in the lower third on the two combined subscales for their gender were in the control group. Each subscale consisted of 3 items to determine the expected involvement for both activities. In the current study, the combined substance using subscale had good internal consistency, with Cronbach’s alpha of $\alpha = .87$. The internal consistency for the overall questionnaire (including all subscales) was $\alpha = .91$.

Using data from our laboratory, there is evidence to indicate that the Heavy Drinking and Illicit Drug Use subscales correlate moderately to strongly with other substance abuse measures. The Alcohol Use Disorders Identification Task (AUDIT) is a self-report questionnaire related to alcohol dependence criteria that has a long history of use in identifying individuals, including undergraduates, at risk for developing alcohol use disorders, and is often utilized as a screen for hazardous alcohol use (Saunders, et al., 1993). In a study of 45 undergraduates completing both the AUDIT and the Heavy Drinking and Illicit Drug Use subscales of the CARE-EI, the Heavy Drinking subscale had a Pearson’s $r = .77$ with the AUDIT while the Illicit Drug Use subscale had an $r = .47$
These moderate to strong correlations support that these two subscales of the CARE-EI are an acceptable measure of substance use.

**Iowa Gambling Task**

A computerized version of the Iowa Gambling Task (IGT) as described in Bechara et al. (2001) was administered to each participant to determine their performance on a measure of risk taking and decision making. The participants were told that the game requires a series of card selections from four decks of cards labeled decks A', B', C', and D' on the computer. Upon each selection, the participants were informed that they had won some hypothetical money by the amount flashing on the screen which is variable based on the deck selection. Some deck selections also resulted in the participants losing money, which was announced on the computer screen post-selection and also varied in quantity based on the deck and its location within the deck. Participants received a $2000 credit to begin the game and were told that the purpose of the game being to win as much money as possible. Each deck contained 60 colored cards: 30 red and 30 black. There were a total of 100 selections per game with a 10 second delay between each selection. Clicking on any card from deck A' or deck B' yielded a gain of $100 whereas clicking on a card from decks C' or D' yielded a gain of $50. After 10 selections from the higher paying decks (A' and B') the participant incurred a net deficit of $250, whereas if selecting from the lower paying decks (C' and D') for 10 cards there would be a net gain of $250 (see Figure 2). This example illustrates that the punishments for selecting from the higher paying decks were disproportionately larger than the punishments from the low paying decks, thus it is more advantageous to frequently select from the lower paying
decks C' and D'. Decks A' and B' resulted in the same net loss over 10 trials but the difference is in the frequency and magnitude of punishment. Deck A' had a higher frequency of punishment but each penalty being of smaller quantity than those for deck B'. Similarly, decks C' and D' had the same net loss over 10 trials with deck C' having a higher frequency of punishment but each being of smaller quantity than those for deck D'.

The validity of the IGT has been demonstrated in patients with damage to the ventromedial prefrontal cortex in a series of studies utilizing both non-computerized and computerized protocols (Bechara et al., 1994; Bechara et al., 2001). The ventromedial prefrontal cortex has been associated with impulsivity and risky decision making, to which the performance impairment in this population is appropriate. In general, when compared to control groups, patients with ventromedial prefrontal cortex damage perform in an impaired fashion on the task even though indicating minimal cognitive impairments otherwise. Control individuals display a tendency towards selecting from the advantageous decks in higher frequencies over the course of the task while patients with ventromedial lesions do not, indicating an insensitivity to future punishment in the face of immediate reward (Bechara et al., 1994; Bechara, Tranel, & Damasio, 2000).

For the present study, the participant’s score was determined following the guidelines established by Bechara et al. (2001): The 100 card selections were broken into quintiles and scored advantageous minus disadvantageous deck selections (C'D' –A'B') to determine the level of performance as the game progressed. Each quintile had a range of scores from +20 to -20, with a positive score indicating a higher number of selections from the advantageous decks and a negative score indicating a higher tendency to select
from the bad decks. Higher positive scores in later quintiles indicated improvement (or learning) from the beginning to the end of the task.

Finally, a modification to the computerized protocol as described by Bechara et al. (2001) was implemented with respect to the time delay between trials. The original computerized protocol utilized a 3 second time delay between card selection trials, but this time delay was increased to 10 seconds per selection in order to accommodate for the psychophysiological measurements obtained and used in the original study.

**Cognitive Modeling Analysis**

Developed by Busemeyer and Stout (2002), the expectancy valence model was designed to determine the motivational, memory/ignorance, and selection impulsivity components of decision making process during the Iowa Gambling Task. The model consists of a parameter for each component: the weight given to losses relative to gains, the updating parameter, and the sensitivity parameter, respectively. The loss weight parameter represents the relative salience of the decision maker to the loss versus the win experienced with each selection. The affective reaction to a win/loss, called a valence and denoted \( v(t) \) is represented by a weighted average \( (w) \) of the losses and wins produced by each card selection as follows: \[ v(t) = w \cdot \text{loss} + (1-w) \cdot \text{win}(t). \]

Smaller values of \( w \) indicate lower sensitivity to losses (Stout et al., 2004).

Upon each card choice, the newly experienced valence produced by that selection changes the expectancy for the deck. The new expectancy for deck \( j \) after trial \( t \) is \( Ev(D_j | t) \), and is the weighted average of the previous expectancy \( Ev(D_j | t-1) \) and the newly experienced valence \( v(t) \): \[ Ev(D_j | t) = a \cdot v(t) + (1-a) \cdot Ev(D_j | t-1). \]
The update rate parameter, $a$, examines the influence of the new experience on the deck expectancies. Large values of $a$ reflect strong recency effects and a faster pace of forgetting or ignoring previous deck selections and outcomes, whereas small values of $a$ indicate the influential role of past outcomes over a long span of deck selections.

Finally, the decision making process can be determined by the consistency of using the expectancies during the deck selections. As also explained in Stout et al. (2004), the sensitivity parameter, $\theta$, measures this level of consistency or impulsivity and is the probability (of choosing a deck) or ratio of the strength of that deck compared to all of the other decks: $$P(\text{deck } j) = \frac{S_j}{S_A + S_B + S_C + S_D}.$$ The strength of a given deck is determined by the expectancy for that deck multiplied by the sensitivity parameter $\theta(t)$: $$S_j = \exp[\theta(t) \cdot Ev(D_j | t)].$$ Thus when sensitivity is low, the decks will be chosen nearly at random whereas when sensitivity is high, the deck with the maximum expectancy will most likely be chosen.

For the hypotheses in the present study involving the expectancy valence parameters, only data from participants whose gambling task performance could be appropriately fit by the model was analyzed (Busemeyer & Stout, 2002). Therefore any participants having an expectancy valence model fit worse than the baseline model (negative $G^2$ value) were discarded from the analyses.

*Wisconsin Card Sorting Test (WCST-64)*

The 64 card version of the Wisconsin Card Sorting Test (WCST-64) was used as a measure of executive functioning where subjects were required to shift from established response sets in order to succeed (Kongs et al., 2000). There were a total of 64 cards all
differing in form (triangle, circle, cross, star), number (1-4), and color (blue, green, red, yellow) of stimuli on the face with no two cards being the same. Four key cards were placed in front of the participant on which to match the 64 cards in the numbered deck, and the participant was not told which category he/she must match the cards to but rather only informed whether the match was correct or incorrect. The participant attempted to match all 64 cards sequentially based on the appropriate category. After 10 consecutive correct responses from a single category the criterion category was switched unbeknownst to the participant, to which he/she must adapt and match based on the new category. This method proceeded until all 64 of the cards were placed for a match with the key cards. For the present study, WCST variables that were used are the number of categories completed, number of perseverative errors, and number of times a loss of set (incorrect choice after 5 correct responses) occurred.

Reports of the test-retest reliability for the WCST have been variable. According to the WCST manual, coefficients ranging from .39 to .72 (mean of .57) have been observed for the WCST variables when testing children and adolescents with a one month gap between administrations (Heaton et al., 1993). Alternatively, reliability coefficients for some of the WCST variables when examined using an average test-retest interval of 6.7 weeks were much higher as follows: .85 for total number of errors, .72 for perseverative responses, .76 for perseverative errors, and .60 for non-perseverative errors (Kongs et al., 2000). In a final study, coefficients greater than .90 were found for all WCST variables when using a test-retest time-span of 2.5 years also with children and adolescents (Ozonoff, 1995). Cicchetti and Sparrow (1981) suggest that generalizability
coefficients of .60 or higher should be regarded as displaying “very good scale reliability,” therefore when taking all these studies together it can be stated that the WCST demonstrates moderate to good reliability. Lastly, the validity of the WCST has been demonstrated in patients with damage to the dorsolateral prefrontal cortex in a numerous studies. It has been shown empirically that patients with dorsolateral lesions complete fewer categories and make greater numbers of perseverative errors on the task relative to controls (Grafman et al., 1990; Janowsky et al., 1989; Robinson et al., 1980).

Go/No Go Task

The Go/No Go task (Horn et al., 2003) is a measure of impulsivity and response inhibition. Participants were asked to make a positive response to a signal when appropriate (Go) or to inhibit the response when not appropriate (No Go). For example, in the first trial the participants were to respond via knocking once when hearing the number 1 and knocking twice when hearing the number 2. A list of the numbers 1 and 2 were subsequently read aloud. Next the participants were asked to reverse the meaning of the words they heard such that they were to knock twice for the number 1 and once for the number 2. A third list of commands were read aloud to which the participants had to knock once should they hear the word “Go” and inhibit a response upon hearing “Stop.” Finally, the commands of the previous trial were also reversed so that the participants were to knock when they were read the word “Stop” and not respond when hearing “Go.” The latter two trials tested the pure response inhibition of the participant. Test-retest reliability has been shown to be high for the four elements of the measure, indicating overall high temporal stability for the test as follows: Pearson’s $r = .79$ for the mean
probability of inhibition, $r = .72$ for the slope of the inhibition function, $r = .61$ for the percent of errors of commission, and $r = .66$ for the standard deviation of the non-signal reaction time (Kindlon et al., 1995). The test was performed on children ages 6-16 with a 2-5 month delay in administration. When used to discriminate between school children and children with disorders of impulse control, the discriminant validity of the task was also high. After controlling for age, the mean probability of inhibition component accounted for a significant amount of the variance ($R^2 = .27$) in group membership (Kindlon et al., 1995). This displays the task’s association with the construct of impulsivity. The variable used in the present study was the total number of errors made out of a possible 40 responses.

Behavioral Inhibition/Behavioral Activation Scale (BIS/BAS)

The Behavioral Inhibition/Behavioral Activation Scale (BIS/BAS; Carver & White, 1994) was created to measure the two motivational systems (behavioral inhibition and activation) that underlie Gray’s theory of personality and behavior (1972). It is a 20 item self-report questionnaire used to assess dispositional BIS and BAS personalities with each question being scored on a scale of 1 = strongly agree to 4 = strongly disagree. While the BIS scale measures behavioral inhibition and the BAS scale results in separate subscales for reward responsiveness, reward drive, and fun seeking (Carver & White, 1994), only overall BIS and BAS scores were utilized in the current study. Based on multiple studies, the BIS/BAS scale maintains a high level of internal reliability. When grouping BAS together, Jorm et al. (1999) observed Cronbach’s alphas of .83 and .76 for BAS and BIS, respectively. Reliability for the BAS subscales is somewhat lower,
although still acceptable (Cronbach’s alphas of .65, .80, and .70 for reward 
responsiveness, reward drive, and fun seeking, respectively; Jorm et al., 1999). Carver 
and White (1994) found test-retest correlations of .66 for BIS, .59 for Reward 
Responsiveness, .66 for Drive, and .69 for Fun Seeking, while Heubeck and colleagues 
(1998) determined even higher coefficients of for three of four scales (ranging from .68-
.83) with a somewhat lower reliability for Reward Responsiveness (ranging from .68-
.73). In examining the convergent and discriminant validity of the BIS/BAS scales, the 
two studies again displayed similarities regarding the scale’s correlation with well 
established measures of extroversion and neuroticism (Manifest Anxiety Scale or EPQ N) 
as well as Positive and Negative Affectivity (PANAS; Heubeck, Wilkinson, & Cologon, 
1998; Carver & White, 1994). The BIS scale showed moderate to strong convergent 
relationships with Manifest Anxiety and Negative Affectivity (.58 and .42, respectively) 
in the Carver & White study while Heubeck et al. displayed correlations between BIS and 
EPQ N and Negative Affectivity of .60 and .37, respectively. Very similar correlations 
between the BAS scales and Manifest Anxiety or Neuroticism were observed (-.13, -.10, 
and -.03 for Carver & White compared to .12, -.09, and -.10 in the Heubeck study) and 
correlations with Negative Affectivity were similarly low (Heubeck, Wilkinson, & 
Cologon, 1998). The BIS score was subtracted from the overall BAS score to determine 
a total BIS/BAS orientation for the participant such that positive scores indicated a larger 
BAS influence and negative scores indicated more of a BIS orientation.
Positive and Negative Affect Schedule (PANAS)

In order to control for state mood, the Positive and Negative Affect Schedule (PANAS) questionnaire was administered. The PANAS is a factor-analytically derived 20 item self-report questionnaire to assess mood, with each question being scored on a scale of 1= very slightly to 5= extremely (Watson, Clark & Tellegen, 1988). Positive affect reflects high levels of enthusiasm, activity, and alertness, whereas negative affect includes a variety of aversive mood states such as anger, contempt, disgust, guilt, fear, and nervousness (Watson, Clark, & Tellegen, 1988). Together, these two orthogonal factors represent affective state dimensions that can be rapidly measured to assess the level of affective influence on gambling task performance. Internal consistency reliabilities for the measure all fall within a relatively high range of scores, for the reliability scores for the positive affect (PA) factor ranges from .86 to .90 while the negative affect (NA) factor ranges from .84 to .87 across varying temporal periods (Watson, Clark, & Tellegen, 1998). The reliability of the scales is unaffected by the respective time periods being examined. Measures of convergent validity for the PANAS are based off correlations with the Hopkins Symptom Checklist (HSCL), the Beck Depression Inventory (BDI), and the STAI State Anxiety Clinic (A-State). The HSCL and BDI are both closely associated with the NA (.70 and .57, respectively) and show negative correlations with the PA (-.25 and -.35). Similarly, the A-State displays both a moderate positive relationship with the NA (.51) and a moderate negative relationship with the PA (-.35; Watson, Clark, & Tellegen, 1998). For the present study, the negative affect score was subtracted from the positive affect score to determine the overall
PANAS score for the participant. Higher scores indicated an overriding positive affect while lower scores indicated an overall negative mood.

Experimental Procedure

For the present study, data from an archival dataset was categorized by gender into substance use and control groups via the results of the Heavy Drinking and Illicit Drug Use subscales of the CARE-EI. In addition, gambling task data was re-analyzed using Busemeyer and Stout’s expectancy valence modeling. All other manipulations to the data were a result of a previous study (Tsanadis, unpublished work).

In the original study, participants were tested in the Clinical Neuropsychology Research Lab in Porter Hall at Ohio University. The participants first completed the informed consent and a demographic questionnaire, followed by the CARE-EI, BIS/BAS, and PANAS questionnaires. This process took approximately 20 minutes. Next, the participants were administered the WCST and the Go/No Go tasks, taking approximately 15 additional minutes. Finally, the participants completed the IGT, which lasted approximately 20 minutes, while connected to a psychophysiological recording instrument (data not used in current study) to measure skin conductance response from the palm side of the medial phalanx on the second and third fingers on the left hand. Following this, the participants were debriefed and permitted to leave. The entire process took approximately 70-90 minutes to complete.

Statistical Analyses

Before testing the hypotheses for the present study, differences in age, affect, and gender between the substance using and control groups were examined, to determine
whether such variables would be used as covariates in subsequent analyses. Data were also tested for normality to determine whether parametric procedures would be utilized.

The first hypothesis was that substance users would perform worse on the Iowa Gambling Task compared to controls. A repeated measures analysis of variance (ANOVA) was used to compare substance users and controls across the mean group scores for each quintile of the IGT. It was expected that there would be a significant time effect (general improvement in performance over time in the pooled sample) and a group effect (generally better performance in the control group relative to the substance using group across all time periods). In addition, a significant interaction between time and group was expected. It was anticipated that the nature of this interaction would be reflected in the third, fourth, and fifth quintiles of the IGT, which was tested with one-tailed independent samples t-tests.

The second hypothesis was that substance users would score lower on the motivational and impulsivity/randomness of selections parameters of the cognitive modeling on the IGT. One-tailed independent samples t-tests were used to compare the two groups on each of the three cognitive modeling parameters. Having significantly lower values for the weightings of losses compared to gains and for the sensitivity parameter (while not for the updating parameter) by the substance using group compared to the controls would support this hypothesis.

The last hypotheses were that substance users would make more errors on the Wisconsin Card Sorting Test, have higher BIS/BAS scores, and also perform worse on the Go/No Go task, as compared to controls. These comparisons were also all analyzed
using individual one-tailed independent samples t-tests to compare scores between substance users and controls. For the WCST, the t-tests were comparing the two groups on their number of categories completed, number of losses of set (failure to maintain set), and number of perseverative errors. It was expected that substance users would have significantly more perseverative errors and losses of set while having fewer categories completed compared to controls. For the BIS/BAS, overall score was used as the dependent variable in the t-test between controls and substance users, with the expectation that substance users would score significantly higher on the BIS/BAS considering high scores to indicate a higher BAS temperament.

Finally, a supplementary analysis was performed to control for general riskiness within all of the analyses proposed. General riskiness was derived by combining all of the subscale scores on the CARE-EI except for Heavy Drinking and Illicit Drug Use. By using a series of ANCOVAs for group differences between substance users and controls on the IGT, cognitive modeling parameters, WCST, and BIS/BAS while making general riskiness a covariate, it was determined whether substance use alone was the main influence on the measures examined or just a function of an overall tendency towards general riskiness.

Results

Of the 91 participants from the previous study (Tsanadis, unpublished work), 67 were utilized in the current study. As described previously, the control (n = 33) and substance use (n = 34) groups were created using the Heavy Drinking and Illicit Drug Use subscales of the CARE-EI questionnaire by dividing the combined scores from the 2
scales into thirds based on gender and denoting the extreme high use group as “substance use” and the extreme low use group as “control.” Table 3 shows that there were no differences in age, \( t(65) = -0.35, p = 0.10 \), affect, \( t(64) = 1.3, p = 0.36 \), or gender, \( \chi^2 (1, N = 67) = 0.02, p = 0.90 \) between the two groups, therefore it was not necessary to use any of these variables as a covariate in the subsequent analyses.

An examination of the normality of the distributions indicated mixed results. Using an Kolmogorov-Smirnov cutoff of \( \alpha = 0.01 \), the IGT quintile, cognitive modeling parameter of attention, and BIS/BAS distributions were normal (\( \alpha = 0.20, \alpha = 0.20, \) and \( \alpha = 0.02, \) respectively), whereas the Go/No Go, the WCST variable distributions (failure to maintain set, categories completed, and perseverative errors), and the cognitive modeling parameters of sensitivity and updating rate were not normal (\( \alpha = 0.00 \) for each). However, according to Tabachnick and Fidel (2001), significance levels of normality are not as important when examining large samples as the values of kurtosis/skew and the look of the normal probability plot. Based on the appearance of normality in the probability plots for the WCST variables (perseverative errors and categories completed) and the cognitive modeling parameter of sensitivity, the use of parametric procedures on these measures was determined to be acceptable. Also, due to the difficulty of interpretation, no transformations were used on these three variables (Tabachnick & Fidel, 2001).

Alternatively, because of the non-normal appearance of the probability plots, non-parametric procedures were necessary for the analysis of the cognitive modeling updating rate parameter. Finally, based on the extreme non-normal distributions of Go/No Go and failure to maintain set, and the lack of variability in scores on these measures in the full
Table 3
Demographics of the Control and Substance Using Groups

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 33)</th>
<th>Subsstance Use (n = 34)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Age</td>
<td>20.47</td>
<td>2.23</td>
<td>19.79</td>
</tr>
<tr>
<td>Affect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANAS</td>
<td>13.76</td>
<td>7.15</td>
<td>14.47</td>
</tr>
<tr>
<td>PA</td>
<td>27.58</td>
<td>6.24</td>
<td>29.32</td>
</tr>
<tr>
<td>NA</td>
<td>13.82</td>
<td>3.02</td>
<td>14.85</td>
</tr>
<tr>
<td>Drug other than</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>marijuana or alcohol</td>
<td>1.18</td>
<td>0.64</td>
<td>3.70</td>
</tr>
<tr>
<td>&gt;5 drinks</td>
<td>2.12</td>
<td>1.58</td>
<td>6.74</td>
</tr>
<tr>
<td>Drinking too quickly</td>
<td>2.00</td>
<td>1.37</td>
<td>6.00</td>
</tr>
<tr>
<td>Smoking marijuana</td>
<td>1.33</td>
<td>1.02</td>
<td>4.76</td>
</tr>
<tr>
<td>Mixing drugs and alcohol</td>
<td>1.12</td>
<td>0.42</td>
<td>4.47</td>
</tr>
<tr>
<td>Drinking games</td>
<td>2.61</td>
<td>1.95</td>
<td>6.47</td>
</tr>
<tr>
<td>Male Percentage</td>
<td>48.50%</td>
<td></td>
<td>50%</td>
</tr>
</tbody>
</table>

Note: PANAS = Positive and Negative Affect Schedule; PA = Positive Affect; NA = Negative Affect.

dataset, these variables were discarded from further analyses. The Go/No Go task shall illustrate the observed extreme non-normalcy of score distributions. Out of a potential 40 errors on the task, 66% of the participants did not perform an error, 25% performed 1 error, 5% performed 2 errors, and the remaining 4% performed between 3 and 6 errors.
Iowa Gambling Task

The first hypothesis sought to examine decision-making capacity within substance users and controls. Using a repeated measures analysis of variance (ANOVA) comparing the mean group scores for each quintile, the first hypothesis was that substance users would perform worse on the Iowa Gambling Task compared to controls. As expected, significant time and group effects were observed (see Table 4). Using a Greenhouse-Geiser epsilon ($\varepsilon = .64$) to correct for violations in homoscedasticity, IGT scores significantly increased as the quintiles progressed when pooling the groups, $F(2, 165) = 23.87, p < .001, \eta^2 = .27$. Also, the results of the ANOVA indicate that in general the control group performed significantly better on the IGT relative to the substance using group across time periods, $F(1, 65) = 3.20, p < .05, \eta^2 = .05$, as observed in both Figure 3 and Table 4. Contrary to expectations, there was no significant interaction between time and group, $F(2, 165) = .32, p = .39, \eta^2 = .01$. Using one-tailed independent samples t-tests to compare groups at each quintile, it can be observed that quintile 5 had a significant group difference, $t(65) = 1.77, p < .05$, although all other time periods showed similar trends. For the fifth quintile, the substance using group made significantly more selections from the disadvantageous decks than did the control group.

Cognitive Modeling Analysis

The second hypothesis was an examination of the role that substance use had on the underlying processes of decision making. One-tailed independent samples t-tests were utilized to compare substance users and controls on the cognitive modeling parameters of the IGT, and it was expected that substance users would score lower on the
motivational and impulsivity/ randomness of selections parameters. A Mann-Whitney U non-parametric procedure was performed for the updating rate parameter. Prior to running the analysis, any data from participants whose gambling task performance was not appropriately fit by the model (negative $G^2$ value) was discarded. Consequently the data from 14 participants were not included in the analysis, indicating a non-fit prevalence of 20.9% and a total N = 53 (n = 26 for controls, n = 27 for substance users) for these hypotheses. Results indicate that there were no significant group differences for any of the modeling parameters, as observed in Table 5. Substance users performed in a similar fashion on the IGT to controls in terms of their attention to losses relative to gains, $t(51) = .65$, $p = .30$, sensitivity towards impulsive or random selections, $t(51) = .49$, 

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 33)</th>
<th>Substance Use (n = 34)</th>
<th>Total (n = 67)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Trial 1-20</td>
<td>-2.67</td>
<td>8.55</td>
<td>-4.76</td>
<td>5.76</td>
</tr>
<tr>
<td>Trial 21-40</td>
<td>3.03</td>
<td>7.02</td>
<td>0.82</td>
<td>7.45</td>
</tr>
<tr>
<td>Trial 41-60</td>
<td>6.36</td>
<td>7.90</td>
<td>3.41</td>
<td>8.44</td>
</tr>
<tr>
<td>Trial 61-80</td>
<td>6.30</td>
<td>10.09</td>
<td>4.65</td>
<td>11.31</td>
</tr>
<tr>
<td>Trial 81-100</td>
<td>9.03</td>
<td>9.29</td>
<td>4.88</td>
<td>9.89</td>
</tr>
<tr>
<td>Total IGT</td>
<td>22.36</td>
<td>27.98</td>
<td>9.06</td>
<td>31.45</td>
</tr>
</tbody>
</table>
Figure 3. Iowa Gambling Task performance separated across quintiles between substance using and control groups.

* 1 tailed p < .05.

p = .31, and updating rate, $\chi^2 = -.51$, p = .31. The eta values for all variables were $\eta^2 < .01$, indicating that non-significance was due to a non-significant proportion of the modeling parameters’ variance being accounted for by substance use as compared to limited power.

Wisconsin Card Sorting Test

The third hypothesis involved substance users’ and controls’ performance on specific variables of the WCST. After the exclusion of the failure to maintain set variable due to extreme non-normality, one-tailed independent samples t-tests compared the two
Table 5
Results of the Cognitive Modeling Analysis of the Performance on the Iowa Gambling Task between Controls and Substance Using Groups

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 26)</th>
<th>Substance Use (n = 27)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Attention</td>
<td>0.46</td>
<td>0.30</td>
<td>0.40</td>
</tr>
<tr>
<td>Sensitivity Updating Rate</td>
<td>0.80</td>
<td>2.91</td>
<td>0.39</td>
</tr>
</tbody>
</table>

groups on the number of categories completed and number of perseverative errors. As expected, there were group differences for the two variables (see Table 6). The substance use group recorded significantly more perseverative errors, t(65) = -1.99, p < .05, and significantly fewer categories completed relative to controls, t(65) = 2.80, p < .05. Overall, the substance use group performed in a more impaired fashion on both measures of the WCST compared to controls.

Behavioral Inhibition/Behavioral Activation Scale

Similar to the WCST variables, the fourth hypothesis, that substance users would have a higher BIS/BAS score, utilized a one-tailed independent samples t-test between the two groups. Higher scores indicate more of a BAS (reward driven) dominance, and the expectation was that this would be observed in the substance using group. Indeed, it can be observed in Table 6 that group differences indicated that controls had significantly smaller BIS/BAS values compared to the substance using group, t(65) = -2.76, p < .05. Therefore it can be inferred from these results that the substance using group has more of a reward-driven BAS dominant personality as compared to the controls.
Table 6
Performance of Controls and Substance Using Groups on the Wisconsin Card Sorting Task and the BIS/BAS Questionnaire

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 33)</th>
<th>Substance Use (n = 34)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>WCST Perseverative Errors</td>
<td>8.70</td>
<td>7.17</td>
<td>12.32</td>
</tr>
<tr>
<td>WCST Categories Completed</td>
<td>3.64</td>
<td>1.45</td>
<td>2.62</td>
</tr>
<tr>
<td>BIS/BAS</td>
<td>17.55</td>
<td>5.37</td>
<td>21.24</td>
</tr>
</tbody>
</table>

Note: WCST = Wisconsin Card Sorting Task; BIS/BAS = Behavioral Inhibition/Behavioral Activation System.

Supplementary Analyses

Using a series of ANCOVAs, the role of general riskiness on all variables of interest was observed. By covarying general riskiness in the analyses, the amount of variance accounted for by both riskiness and substance use could be examined on the measures administered. Across all ANCOVAs, general riskiness did not account for a significant proportion of variance for any of the dependent measures (see Table 7), indicating that general riskiness did not appear to be the driving force behind substance use’s effects. The reanalysis of the IGT showed that covarying riskiness, while decreasing the substance use group effect significance level from \( p < .05 \) to \( p < .10 \), had no influence on decision-making performance on its own, \( F(1, 64) = .02, p = .45 \).

Similarly, the covariate was not significant for any of the cognitive modeling parameters [\( F(1, 50) = .01, p = .49 \) for attention, \( F(1, 50) = .20, p = .33 \) for sensitivity, and \( F(1, 50) = \).]
Table 7  
**ANCOVA Analyses with Substance Use as Fixed Variable and the Covariate of General Riskiness for the Dependent Variables of Interest**

<table>
<thead>
<tr>
<th></th>
<th>Values of Substance Use</th>
<th>Values of Covaried General Riskiness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F value</td>
<td>p value</td>
</tr>
<tr>
<td>IGT</td>
<td>2.23</td>
<td>0.07</td>
</tr>
<tr>
<td>Modeling Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention</td>
<td>2.85</td>
<td>0.30</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>4.60</td>
<td>0.26</td>
</tr>
<tr>
<td>Updating Rate</td>
<td>0.44</td>
<td>0.25</td>
</tr>
<tr>
<td>WCST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>5.97</td>
<td>0.01</td>
</tr>
<tr>
<td>Categories Completed</td>
<td>5.17</td>
<td>0.02</td>
</tr>
<tr>
<td>BIS/BAS</td>
<td>2.93</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*Note: IGT = Iowa Gambling Task; WCST = Wisconsin Card Sorting Test; BIS/BAS = Behavioral Inhibition/Behavioral Activation System.*

... .85, p = .18 for the updating rate]. Again, the extremely low eta values for the three parameters (η² = .02 for updating rate and η² < .01 for both attention and sensitivity) indicate that the results were not due to low power, but rather that general riskiness simply had minimal influence on the parameters. In the final few analyses, both the number of perseverative errors, F(1, 64) = 5.97, p < .01, and the categories completed, F(1, 64) = 5.17, p < .05, on the WCST and the BIS/BAS, F(1, 64) = 2.93, p < .05, still showed significant group differences, while the covariate of general riskiness did not account for significant proportions of variance [F(1, 64) = 2.02, p = .08 for perseverative errors; F(1, 64) = .07, p = .40 for categories completed; F(1, 64) = 1.86, p = .09 for
In summary, controlling for general riskiness across all the analyses showed that riskiness never accounted for significant levels of variance related to the variable of interest and only once did it cause the substance use group effect to drop below a significant level.

Discussion

The current study contributed to the substance use literature by exploring the underlying processes involved in the decision-making impairment of undergraduate substance users on the Iowa Gambling Task. Additionally, the study examined executive functioning and reward driven personality among the undergraduate substance users via the WCST and the BIS/BAS personality scale, respectively.

Iowa Gambling Task

The analyses revealed significant time and group effects for the IGT, but not a significant interaction between time and group. The significant time effect means that performance improved over time when combining all participants, such that more total card selections were made from the advantageous decks (C' and D') during the later quintiles compared to early on averaging across all participants. The significant group effect indicates that substance users performed significantly worse across quintiles on the IGT relative to controls, meaning that substance users had a lower net score, by selecting more cards from the disadvantageous decks (A' and B') than did controls. This trend of more impaired substance user performance was observable across all quintiles and reached significance in the 5th quintile. Unfortunately, no interaction existed between time and group, meaning that over time substance users did not systematically perform in
a more impaired fashion or that the control group had a faster learning curve. Rather, as Figure 3 shows, a non-significant difference in IGT performance existed during quintile 1 between the two groups, which, as the quintiles progressed, eventually reached significance but primarily remained the same throughout the task.

The study’s findings of significant group and time main effects between substance users and controls on the IGT are consistent with previous research. Numerous studies from the Bechara laboratory have indicated that substance abusers commonly perform in a more impaired manner on the IGT relative to controls, and that a general performance improvement occurs over time when summing all groups (Bechara et al., 2001; Bechara & Damasio, 2002; Bechara & Martin, 2004). For example, Bechara & Damasio (2002) found that when comparing substance abusers, ventromedial cortex lesioned patients, and controls on the IGT, significant main effects of group and block (time) existed. Post hoc results revealed that the substance abusers selected significantly less cards from the advantageous decks than controls. Similarly, other laboratories examining these main effects have found significant results. Whitlow et al. (2004) found both a main effect of group and time for long-term heavy marijuana users, such that the net score on the IGT for the marijuana users was significantly lower than controls. Finally, the present results were consistent with multiple studies examining only a group effect. Fein et al. (2004) found that gambling task performance was significantly lower for abstinent alcoholics compared to controls, Grant et al. (2000) observed impairment in drug users compared to drug-naïve control participants, and Petry (2001) saw similar results to the prior two
studies when examining both pathological and non-pathological gambling substance abusers versus controls.

Conversely, the present study’s findings regarding a non-significant interaction effect between group and time are inconsistent with the literature. Whitlow et al (2004) also examined an interaction effect in their long-term heavy marijuana study mentioned above and found that performance on the IGT significantly differed between the groups depending on the quintile. Controls began to choose significantly more cards from the advantageous decks (C’ and D’) by quintile 3, while long-term heavy marijuana users selected more from the disadvantageous decks (A’ and B’) throughout. Post-hoc analyses revealed that the mean net score between long-term marijuana users and controls was not significantly different for quintiles 1 and 2, whereas significantly lower scores existed for the marijuana using group for quintiles 3-5. Similarly, significant interaction effects were observed in both Bechara & Martin (2004) and Bechara & Damasio (2002). Substance abusers actually performed better than controls during the first quintile before the trend in performance was reversed in the third, fourth, and fifth blocks, indicating the large difference in performance based on the time location of the trial (Bechara & Martin, 2004).

It is possible that the present study’s contrary results may be due to differences in severity of substance use/abuse relative to prior studies. In the present study, undergraduates reporting the likelihood of combined heavy use of alcohol and drugs were used, whereas severity and chronicity of abuse was more extensive in previous work. Whitlow et al. (2004) utilized long-term marijuana users with at least 5 years of high
frequency consumption, and both Bechara & Martin (2004) and Bechara & Damasio (2002) tested clinically diagnosed substance abusing populations prior to their completion of substance abuse rehabilitation. The differences in chronicity and severity may be reflective of a more fundamental difference in high risk personality, such that the Whitlow and Bechara studies may have utilized participants with more riskiness or impulsivity which resulted in both a greater decrease in decision-making capacity and consequently worse severity of substance abuse. Furthermore, the increased chronicity and severity of substance abuse may have resulted in additional frontal lobe deficits as a function of increased duration of substance abuse and consequently further neuropsychological impairment. In fact, the results show that for most quintiles only a non-significant trend of decision-making impairment was observed in the current study between substance users and controls, whereas significant impairment was seen with more severe substance abusing populations. Such differences in sample may be enough to distinguish the studies with non-significant and significant interaction effects. However, this explanation should not invalidate the use of an undergraduate substance using population to examine decision-making impairment, for the main effects of time and group on decision-making were readily apparent. Indeed, an examination of the mean IGT score for the substance use group shows that the value was 9.06, which is below the total score cutoff of +10 that Bechara has commonly used to demarcate decision-making impairment on the IGT (Bechara & Martin, 2004). Clearly, the present study indicates that undergraduate substance users, seemingly without decades of abuse,
do show a relative deficit in decision-making impairments that is more difficult to
attribute to frontal lobe damage consequent to substance abuse.

Cognitive Modeling Analysis

The attempt to separate the underlying psychological processes influencing
decision-making impairment on the IGT into motivational, cognitive, or
impulsive/randomness parameters using the expectancy valence model was not
successful. Table 5 shows that there were no significant group differences for any of the
three modeling parameters, meaning that substance users displayed similar levels of
motivational significance towards rewards (weighing of losses relative to gains), memory
towards prior outcomes (updating rate), and consistency in applying the prior
expectancies when making a new selection (sensitivity), relative to controls. These
results occurred even though significant differences in IGT performance existed between
groups as shown above.

These findings were not anticipated according to prior research. Heightened
weighting of losses and more erratic card selections by the substance using group were
expected based on the study by Stout et al. (2004) examining differences in the cognitive
modeling parameters of the expectancy valence model on IGT performance between
cocaine users and controls. They found that motivational and choice consistency factors,
but not learning/memory/ignorance, were primarily responsible for the decision-making
deficit of the cocaine abusers during the task, which fit theoretically into the idea that
motivational systems of reward play a major role in drug abuse (Stout et al., 2004). The
differences between the present study’s findings and those of Stout et al. (2004) may be
explained in multiple ways. First, as already mentioned for the IGT, it is possible that the
differences in severity of substance users/abusers between the two studies may account
for their diverse findings. Stout et al. utilized male participants 37 years old on average
reporting regular cocaine abuse at the time of the study, giving them a greater likelihood
of increased chronicity than the substance using population utilized in the present study.
By virtue of the lessened chronicity and severity, the population in the current study may
therefore have not abused substances long enough to have motivational or choice
consistency effects observed within their decision-making impairments. It is possible
that such underlying processes could only be displayed after years of substance abuse.

Alternatively, issues with the expectancy valence model itself may be the source
of inconsistency between the two studies. The Stout et al. (2004) study has been thus far
the only project to examine the cognitive modeling parameters on substance abusers, and
did so with only an n = 12 in the experimental group. While showing promise, the model
used is far from established when using substance abusing populations. It is possible that
the expectancy valence model is not the ideal model to categorize decision-making
deficits, particularly since over a fifth of the dataset (20.9% for current study; 30% for
Roe, personal communication, April, 2005; 19% for Stout et al., 2004) must be removed
because of “goodness of fit” issues. By doubling the sample size in the experimental
group (n = 27), the current study may have exposed the fact that group differences in the
parameters of Stout’s study do not really exist, but were just present due to the small
misrepresentative sample.
Another potential explanation is that a modification to the IGT protocol in the present study may be responsible for the differences in results within the two studies. The original description of the IGT, as used by Stout et al. (2004), utilized a 3 second time delay between card selection trials (Bechara et al., 2001), but in the current study this delay was increased to 10 seconds per selection due to the psychophysiological measurements obtained in the original study. A study by Bowman et al. (2005) examined performance on the IGT when variations in time delays between selections were utilized. There were no differences in decision making between groups with a normal delay (3 seconds) as compared to an extended delay (6 seconds), for both performed within the normal ranges for controls. While Bowman’s study appears to indicate that the increased time delay in the current study may not have influenced IGT performance, the same may or may not be true for the more sensitive underlying decision-making processes. With such few studies examining the expectancy valence model at present, it is unknown how the effect of time delay may have altered the motivational and memory parameters of the modeling, therefore this modification cannot be ignored. As indicated by the number of potential explanations described above, further studies examining the relationship between substance abuse and the underlying processes for decision making deficits are necessary to resolve these inconsistencies in results.

**Wisconsin Card Sorting Test**

The examination of particular variables of the WCST revealed that substance users and controls differed in both their number of perseverative errors and number of categories completed. The substance use group recorded significantly more perseverative
errors and fewer categories completed relative to controls, meaning that in general the
substance use group was more impaired on this measure of executive functioning.
Perseverative errors are a measure of the tendency a participant has to incorrectly return
to a previously successful strategy when the new set is unknown, thus a high number
indicates more of a level of impulsively within the participant (Kongs, 2000). The
number of categories a participant completes indicates the success obtained in switching
set strategies and therefore the overall executive functioning capacity.

These results are consistent with the majority of the findings in the literature
regarding the WCST and substance abuse. As observed in Table 2, most studies
examining WCST performance by substance abusers displayed findings of impairment on
some variable relative to controls. For example, all four studies from the Bechara
laboratory that examined this relationship found that substance abusers performed more
perseverative errors than controls (Bechara & Damasio, 2002; Bechara et al., 2001;
Bechara & Martin, 2004; Bechara, Dolan, & Hindes, 2002) while two of the studies
determined that substance abusers completed significantly less categories than controls
(and a third had a non-significant trend in that direction; Bechara, Dolan Hindes, 2002;
Bechara & Martin, 2004). Other labs have found similar results. Shoqueirat et al. (1990)
found that Korsakoff’s alcoholics were impaired on the number of categories completed,
number of perserverations, and total number of errors compared to both controls and
other amnesiacs; Hoff et al. (1996) found a greater number of total errors and
perseverative responses for cocaine abusers; Brokate et al. (2003) found fewer categories
completed, more errors and more perseverations for alcoholics relative to controls.
Alternatively, the present findings are inconsistent with the two studies from the Grant laboratory that utilized the WCST with substance abusers. While one had trends in the direction of impairment, both studies (Grant et al., 2000; Ernst et al., 2003) found no significant differences between substance abusers and controls on any variable of the WCST. It is difficult to explain the inconsistencies in the results, for differences in the severity of abuse would not appear to be relevant in this situation. The inclusion criteria for the participants in the Grant studies were only that they had to possess a relatively chronic history of abuse, regardless of their level of treatment rehabilitation. An examination of Table 2 indicates that participants from almost all other studies were required to attend substance abuse rehabilitation for some length of time prior to participation, meaning that these participants may have received help with their substance abusive personality prior to participation in the studies. Both the participants who received help for substance abuse (the majority of studies in Table 2) and the undergraduate substance users (the present study) performed in an impaired manner on the WCST compared to controls, whereas abusers not receiving rehabilitation (the Grant studies) performed unexpectedly similar to controls. Should severity be the cause of the inconsistencies, it would not make sense that the undergraduate users and treated abusers would perform worse than abusers without rehabilitation at all. Alternatively, IQ may be used to explain the differences between the current study and both Grant et al. (2000) and Ernst et al. (2003). Most substance abusing studies statistically control for IQ when examining variables on the WCST, for substance abusing groups commonly have lower average IQs than control groups. No information regarding IQ was available in the data.
used for the present study, although the fact that all participants were in college might suggest there were not extreme differences within the two groups. Also, since other studies in Table 2 have controlled for IQ and still found significant results, IQ may not be adequate to explain these differences in results either.

The present study’s findings provide support that substance using undergraduates as a group display impairments not only in decision making, but in executive functioning as well. The dorsolateral prefrontal cortex has long been linked to performance on executive functioning tasks, therefore it appears that the dorsolateral prefrontal cortex may also have an important role in substance use/abuse based on the impairments observed on the WCST. As will be discussed later, other neuropsychological data also appear to support this notion of both orbitofrontal and the dorsolateral prefrontal cortex being important regions of the brain in regards to substance abuse.

Behavioral Inhibition/Behavioral Activation Scale

The analysis of the final hypothesis, that substance users would have higher BIS/BAS scores than controls, revealed a significant group difference in the anticipated direction. The larger scores possessed by the substance users indicates that the substance using group tended to have more of a reward-driven BAS dominant personality as compared to controls. These results are not surprising since, according to Gray’s theory (1972, 1990), substance abuse is considered an overwhelming of the behavioral inhibition system (BIS) by the behavioral activation system (BAS). By participating in the abuse of substances, the substance user’s personality is being dominated by its desire for
stimulation or reward in spite of the sensitivity towards the negative consequences associated with substance abuse.

The current study’s findings are consistent with previous literature suggesting that high scores on the BIS/BAS scale are related to substance abuse. For example, Johnson, Turner, & Iwata (2003) compared behavioral inhibition and behavioral activation levels along a broad range of psychopathologies such as depressive disorders, anxiety disorders, substance abuse, and ADHD in individuals 19 - 21 years of age. Their results concluded that high BAS scores were significantly associated with lifetime drug abuse as well as lifetime alcohol abuse without comorbid anxiety and the BIS scale was associated with anxiety and depressive disorder. The BAS scale did not have significant associations with any other disorders in the study, including ADHD or conduct disorder (Johnson et al., 2003). In addition, Von Honk et al. (2002) compared undergraduates with extreme high and low BIS/BAS scores using their performance on the IGT. Participants whose personality tended towards behavioral inhibition (low BIS/BAS group) performed significantly better on the IGT than the group with high BIS/BAS scores. These results are consistent with the current study because the substance using group was associated with both impaired IGT performance and higher BAS dominated scores, indicating the relationship between the three constructs.

The current study provides support that personality characteristics may have a role in substance use/abuse. As shown by the study’s findings, substance use/abuse is associated with higher levels of behavioral activation. Pervasive high risky personality traits, such as impulsivity, appear to be crucial to the development of substance abusive
behaviors, for BAS is commonly used to describe the dimension of impulsivity based on its responsiveness to incentives and reward. Indeed, Petry (2001) and many others have shown that substance abusers tend to score higher on measures of impulsivity than controls (Patton et al., 1995; Tcheremissine et al., 2003). As will be discussed in the Implications section, this research should underscore the importance that personality variables have on substance abuse.

Limitations

The present study has several limitations based on the utilization of archival data. First, all analyses are comparing controls to substance users instead of substance abusers, due to the characteristics of the high risk questionnaire administered in the original study. The CARE-EI is a measure of the likelihood of participation in risky behavior over the next six months, as compared to a questionnaire identifying participants engaging in clinically defined substance abusive behaviors. Given the de-identification of the dataset, it was not possible to contact those who participated in the original study and administer a more clinically based substance abuse measure post hoc. Alternatively, the experimental and control groups were based on extreme scores from the combined Heavy Drinking and Illicit Drug Use subscales of the CARE-EI. Consequently, the “substance user group” designation by in the current study is inherently less severe than the “substance abusing group” utilized in many other studies in the literature, and therefore inconsistencies with other research may be because the substance problems associated with the present study’s experimental group are more minimal in comparison.
The use of a self-report questionnaire for the determination of substance use may have also been problematic. Most other substance abuse studies have empirical evidence (e.g., drug rehabilitation) that their participant populations abuse severely, whereas self-report information regarding substance use/abuse may be inaccurate for a number of reasons. Due to not wanting to admit illegal activities, many substance users may have under-reported their use. Or, given the normative nature of high substance use, particularly alcohol use, in the undergraduate culture, what would be considered high use in another cohort may not be clinically relevant in an undergraduate sample. Given that the present study was an archival analysis, the design was limited in that there was no further verification of individual’s substance use using clinically validated scales.

An attempt to examine the magnitude of the substance-severity issue was to perform a supplementary analysis to determine whether differences in the measures of interest would remain between substance using groups and controls after general riskiness was statistically controlled. The results indicated that significant differences between groups on the measures administered were due to substance use alone, as compared to riskiness being the driving force behind substance abuse’s effects. For the personality, executive functioning, and cognitive modeling variables, general riskiness did not account for a significant proportion of the variance, whereas substance use did. A similar result was observed for the decision-making task, except that substance abuse slipped just beyond the level of significance. These results are important because even though substance use groups were used instead of substance abuse, the severity of substance problems being examined was still powerful enough to show differences
independent of general riskiness. However, the present study’s method of controlling for riskiness, a post hoc breakdown of the CARE-EI subscales, is limited by its lack of construct validity. As will be discussed further in the Implications section, both the use/abuse of substances and presence of decision-making and executive-functioning impairments may be mediated by related constructs such as impulsivity, sensation seeking, and a reward-driven personality. Thus, the present study could have been improved had other measures of the “riskiness” construct also been administered.

Lastly, a final limitation was that the study’s sample was rather homogenous with respect to ethnicity and age. This was based on the location of data collection, for recruitment occurred at a Midwestern university containing minimal ethnic diversity. Consequently, because of such a homogenous population being sampled, the results of the study may not generalize to additional populations.

Implications of the Findings and Future Directions

The findings of the current study appear to provide information on a number of questions commonly raised within the substance abuse/decision-making literature. The first is whether the orbitofrontal cortex is the sole brain region responsible for behavioral impairments in substance users/abusers as Bechara and Damasio contend. The second question asks whether complex behavioral decisions can be decomposed into simpler elements in an attempt to examine the underlying processing of decision making using the expectancy valence model of Busemeyer and Stout. The final question involves whether brain damage due to years of substance abuse can lead to poor decision making
or that biological and impulsive personality traits predispose an individual to a life of substance abuse.

The present study presents evidence that both the orbitofrontal and the dorsolateral prefrontal cortices may be important in the behavioral impairments displayed by substance users. It is necessary to note, however, that regardless of the consistency with other neuropsychological data, behavioral deficits on neuropsychological tasks are not sufficient to identify a brain region’s involvement with accuracy. Due to the complexity of both the constructs measured as well as the massive network of neural connections between brain regions, behavioral impairment may be a consequence of dysfunction in any number of areas associated with the construct as compared to one specific brain region. While extensive neuroimaging studies have supported the link between both the dorsolateral cortex and executive functioning as well as the orbitofrontal cortex and decision making, inferences in the present study of neuroanatomical dysfunction based on behavioral deficits must be drawn with caution.

In the current study, substance using groups were impaired on both the WCST and the IGT, with each traditionally considered to be neuropsychological tools for the identification of executive functioning and decision-making deficits, respectively. These measures have commonly also been used to isolate prefrontal impairment in the dorsolateral and orbitofrontal cortices, respectively. Neither of the current results was surprising considering the overwhelming consistency in the literature regarding substance abusers’ performance on these two tasks (Tables 1 and 2). However, these findings are unexpected if only considering the neuroimaging and neuropsychological data that have
isolated the orbitofrontal cortex in behavioral impairments of substance abuse. Neuroimaging studies have consistency linked the pathophysiology of drug dependence to the orbitofrontal cortex (London et al., 2000; Adinoff et al., 2003), and for many years the Bechara laboratory has isolated the orbitofrontal cortex as the brain region involved in decision-making impairment of substance abusers, utilizing similarities in performance deficits between substance abusers and patients with lesions to the ventromedial prefrontal cortex (a subregion of the orbitofrontal cortex) as evidence (Bechara et al., 1994). There appears to be a gap in the literature involving this relationship between decision making, executive functioning and substance abuse. Specifically, the present study contends that both decision making and substance abuse are not orbitofrontal specific. As mentioned in the introduction, Manes et al. challenged Bechara’s claims with their 2002 study identifying patients with lesions to the dorsolateral and dorsomedial prefrontal cortices as impaired on the IGT, whereas patients with lesions to the orbitofrontal cortex performed at the same level as controls. More recently, Fellows & Farah (2005) found that unilateral damage to the dorsolateral prefrontal cortex led to impaired IGT performance of a similar magnitude to the effect of the ventromedial (orbitofrontal) prefrontal cortex damage. In the least, the results of the latter two studies plus the current one indicate that isolated impairment on the IGT cannot be used to infer solely ventromedial or orbitofrontal cortex dysfunction. Also, the long history of executive functioning impairments in substance abusers precludes the claim of orbitofrontal specificity to substance abuse. When linking the WCST and the IGT results
from the present study together, it appears that substance users may have deficits in both the orbitofrontal and the dorsolateral prefrontal cortex.

More comprehensive work will be required to establish the mutual roles of the dorsolateral and orbitofrontal cortices in decision making and substance abuse. A future study should therefore include age-, gender-, and IQ-matched substance abusers, ventromedial lesioned patients, dorsolateral lesioned patients, and controls in a comparison of IGT and WCST performance. Baseline functional MRI analyses can be taken for the four groups to ensure/locate appropriate neurological deficits as well as during the tasks to determine what brain regions were stimulated or impaired while performing. Results of a well-controlled study such as this will link the inconsistent neuropsychological and neuroanatomical findings from previous studies about the dorsolateral and orbitofrontal cortices’ relationship in substance abuse.

In terms of the second question acknowledged by the current study, the validity of Busemeyer and Stout’s expectancy valence model cannot be determined with regard to its use with substance using populations. The null findings for all three cognitive parameters indicate that the model was not successful in identifying the underlying cognitive processes behind decision-making impairments in substance users within the current study. Decision-making deficits on the IGT were displayed by the substance using group, but group differences on the parameters explaining why these impairments occurred could not be found. Due to questions raised by the inconsistencies in results between the current study and Stout et al. (2004), further examination of the expectancy valence model on IGT performance by substance users/abusers needs to occur. More
research into these underlying decision-making processes is required before Stout et al. (2004) should be accepted as fact. Bechara has already adopted the model for use in his future studies (Bechara et al., 2005), prior to any replication studies involving substance abusers being published. It is possible that other studies utilizing large sample sizes of substance users/abusers will find similar null results. Alternatively, Stout’s findings may be supported; regardless, additional replication is needed.

Third, the present study’s findings present implications for the issue regarding the direction of cause and effect of decision making and substance abuse. Namely, are decision-making deficits a function of neurological damage based on substance abuse behaviors or is substance abuse a result of personality and biological traits pervasive over the lifetime of a substance abuser? Many neuroimaging studies have presented their results in the light that substance abuse leads to brain damage (Franklin et al., 2002; Lui et al., 1998), and these neural deficits are then expected to result in impaired decision making and other impulsive behaviors. Indeed, as the basis for Stout’s cognitive model, she states that “Neuroscience research has found that drug abuse damages regions of the brain which are responsible for processing reinforcement” (Stout et al., 2004, pp. 746). Based on this reasoning, deficits in decision making should surface only after a long enough duration of substance abuse to allow for neural damage to occur, which should be in the magnitude of years according to Lui et al. (1998).

Instead, the current study proposes that underlying biological and personality traits are at the core of impulsive behavioral styles that result in a substance abusive persona. The present study has shown that high substance-using undergraduates,
averaging only 19.8 years of age, display impairments in decision making and executive function, as well as possess impulsive, reward-driven personalities to a greater extent than controls. This population is probably too young to have abused substances for a long enough duration to incur the magnitude of brain damage observed in many of the neuroimaging studies, but yet the neuropsychological deficits are still present. Blum’s Reward Deficiency Syndrome states that there is clearly a biological component to the underlying associations between behavioral disorders like substance abuse, compulsive gambling and eating, and Tourette’s, all of which can have a physical manifestation involving the personality trait of impulsivity given lessened D2 dopamine receptor prevalence and subsequent decreased dopaminergic activation (Blum et al., 1996). The finding of significant differences between the BIS/BAS scales of control and substance users in the current study indicates that even as undergraduates, substance users have a higher level of reward drive and impulsivity. It is this reward-driven personality, seemingly due to the dysfunction of D2 dopamine receptors in the brain, which appears to lead highly risky/impulsive adolescents and undergraduates to eventual substance abuse. In fact, Fishbein suggests that not only is there evidence that traits such as novelty-seeking, approach behaviors, impulsivity, and poor decision making are precursors to drug abuse, but chronic drug abuse may in turn exacerbate existing deficits (Fishbein et al., 2005). This exacerbation compromises the ability to execute conservative judgments, therefore promoting the spiral of cause and effect between decision making/riskiness and substance abuse (Fishbein et al., 2005). In agreement with Fishbein et al., Dawe et al. (2004) has postulated that individuals high in BAS
dominance are more receptive to drug use and subsequent reinforcement based on involvement of the striato-thalamo-orbitofrontal pathway. The orbitofrontal cortex is closely connected with dopaminergic pathways in the striatum and the limbic system, which receive projections from the nucleus accumbens via the thalamus, ventral tegmental area, amygdala, and the hippocampus. BAS dominant individuals possess less efficient inhibitory dopamine synapses in the striatum, leading to a lower reward-activation threshold in the nucleus accumbens and consequently a greater level of reinforcement by the drug. Increases in dopamine release due to substance abuse in BAS dominant individuals will further disrupt this dysfunctional inhibitory pathway, leading to a loss of control for the drug. Based on the utilization of young substance users as well as the pervasive reward-driven personality traits expressed, it is apparent that personality may initially lead to abuse instead of the opposite.

To thoroughly investigate this issue, longitudinal studies must be conducted to examine personality tendencies and substance use/abuse from adolescence into adulthood. The present study has indicated that it is appropriate to examine pre-abusive substance users (undergraduates) on the above measures, and since genetics and personality may be driving substance abusive behavior it should also be acceptable to sample from even younger substance using population groups. Only when the decision-making and personality traits of substance abusers have been examined beginning in adolescence, presumably before most substance abusers have even consumed, can the issue of underlying personality traits leading to substance abuse be empirically validated. Otherwise, some may contend that even minimal substance usage will lead to the early
stages of neural damage as a result of consumption, consequently confounding the cause
and effect of the relationship between personality, behavioral performance and substance
abuse. While difficulties of cost, attrition, and manpower to run such an encompassing
study are evident, the results would truly confirm these hypotheses stated presently.
References


*Abstract for Society of Neuroscience*, 25, 551.


Appendix A: Demographic Questionnaire

Id _______________________ Age: _____ Gender: male female

Current level of education: freshman sophomore junior senior

Handedness left right

1. Have you ever experienced a head injury or concussion? yes no

IF YES, CONTINUE WITH 2. IF NO, SKIP TO 7

2. When did you experience your concussion/head injury? (date)

3. Did your concussion/head injury involve a loss of consciousness (please circle) yes no
   If yes, how long did you lose consciousness (in min, hours, days)?

4. What was the length of posttraumatic amnesia (i.e., how must time before and after the injury were you awake but don’t remember what happened)?

5. Were you hospitalized for your head injury/concussion (please circle) yes no

6. Did a health care provider diagnosis you with a head injury/concussion (please circle) yes no

7. Do you have a learning disability or attention deficit disorder? yes no
   If yes, please specify what diagnosis

8. Do you have any neurological history other than head injury (ex, seizures, brain tumor)? yes no
   If yes, please list diagnosis ________________________________

9. Are you currently receiving treatment for psychological problems? yes no
   If yes, please list diagnosis ________________________________
CARE

Rate the likelihood that you will engage in each of the following activities during the next six months:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trying/using drugs other than alcohol or marijuana</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>2. Missing class or work</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>3. Grabbing, pushing, or shoving someone</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>4. Leaving a social event with someone I have just met</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>5. Driving after drinking alcohol</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>6. Making a scene in public</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>7. Drinking more than 5 alcoholic beverages</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>Not at all likely</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>8. Not studying for exam or quiz</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Not at all likely</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>9. Drinking alcohol too quickly</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>10. Disturbing the peace</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>11. Damaging/destroying public property</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>12. Sex without protection against pregnancy</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>13. Leaving tasks or assignments for the last minute</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>14. Hitting someone with a weapon or object</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>15. Rock or mountain climbing</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>16. Sex without protection against sexually transmitted diseases</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>17. Playing non-contact team sports</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td></td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>---</td>
<td>------------------</td>
</tr>
<tr>
<td>18. Failing to do assignments</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>19. Slapping someone</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>20. Not studying or working hard enough</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>21. Punching or hitting someone with fist</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>22. Smoking Marijuana</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>23. Sex with multiple partners</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>24. Snow or water-skiing</td>
<td>Extremely Likely</td>
</tr>
<tr>
<td>25. Mixing drugs and alcohol</td>
<td>Extremely Likely</td>
</tr>
</tbody>
</table>
26. Getting into a fight or argument
Not at all likely        Extremely Likely
1    2    3    4    5    6             7

27. Involvement in sexual activities without my consent
Not at all likely        Extremely Likely
1    2    3    4    5    6             7

28. Playing drinking games
Not at all likely        Extremely Likely
1    2    3    4    5    6             7

29. Sex with someone I have just met or don’t know well
Not at all likely        Extremely Likely
1    2    3    4    5    6             7

30. Playing individual sports
Not at all likely        Extremely Likely
1    2    3    4    5    6             7
Appendix C : BIS/BAS

BIS/BAS

Participant Number__________________

Read each statement below. On the blank line next to each statement, rate how strongly you agree or disagree using the scale below:

1 = strongly agree
2 = agree
3 = disagree
4 = strongly disagree

Make sure you rate all of the 20 items. Rate each item only once. If you aren’t sure, make your best guess.

1. If I think something unpleasant is going to happen I usually get pretty “worked up.” ___

2. I worry about making mistake. ___

3. Criticism or scolding hurts me quite a bit. ______

4. I feel pretty worried or upset when I think or know somebody is angry at me. ___

5. Even if something bad is about to happen to me, I rarely experience fear or nervousness. ___

6. I feel worried when I think I have done poorly at something. ____

7. I have very few fears compared to my friends. ___

8. When I get something I want, I feel excited and energized. _____
9. When I am doing well at something, I love to keep at it. ______
10. When good things happen to me, it affects me strongly. ______
11. It would excite me to win a contest. ____
12. When I see an opportunity for something I like, I get excited right away. _____
13. When I want something, I usually go all out to get it. ___
14. I go out of my way to get things I want. ______
15. If I see a chance to get something I want, I move on it right away. ____
16. When I go after something I use a “no holds barred” approach. ______
17. I will often do things for no other reason than that they might be fun. ______
18. I crave excitement and new sensations. ______
19. I’m always willing to try something new if I think it will be fun. _____
20. I often act on the spur of the moment. ______
Appendix D: PANAS

PANAS

This scale consists of a number of words that describe different feelings and emotions.

Read each item and then mark the appropriate answer in the space next to that word.

Indicate to what extent you feel this way right now, that is, at the present moment. Use the following scale to record your answers.

1 very slightly or not at all 2 a little 3 moderately 4 quite a bit 5 extremely

____ interested ____ irritable
____ distressed ____ alert
____ excited ____ ashamed
____ upset ____ inspired
____ strong ____ nervous
____ guilty ____ determined
____ scared ____ attentive
____ hostile ____ jittery
____ enthusiastic ____ active
____ proud ____ afraid
Appendix E: WCST-64 Scoring Form
Appendix F: Go/ No Go

3. Go/NoGo (verbal regulation)

A. Knocking twice or once,

Habitual meaning (twice for twice, once for once):

1____ 2____ 1____ 2____ 1____ 2____ 2____ 1____ 2____

# of errors................................................................. ____

Loss of task set............................................................. ____

Reverse meaning (once for twice, twice for once):

1____ 2____ 1____ 2____ 1____ 2____ 2____ 1____ 2____

# of errors................................................................. ____

Loss of task set............................................................. ____

B. Go and stop,

Habitual meaning (go for go, stop for stop):

S____ G____ S____ G____ S____ G____ G____ S____ G____

# of errors................................................................. ____

Loss of task set............................................................. ____

Reverse meaning (stop for go, go for stop):

S____ G____ S____ G____ S____ G____ G____ S____ G____

# of errors................................................................. ____

Loss of task set............................................................. ____