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The relative impact of nicotine dependence versus other substance dependence on decision-making

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THE RELATIVE IMPACT OF NICOTINE DEPENDENCE VERSUS OTHER SUBSTANCE DEPENDENCE ON DECISION-MAKING

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Abstract

Research has indicated that individuals who are dependent on substances may have decision-making deficits that contribute to their continued substance use. Previous studies have shown that substance-dependent individuals focus more on the immediate rather than the delayed consequences of their actions, and more rapidly discount rewards that are available after a delay than individuals without a history of substance dependence. The present study compared the performance of four groups of individuals on the Gambling Task and the Delayed Discounting Task. The groups were (a) heavy smokers with comorbid substance dependence, (b) heavy smokers with no history of substance dependence, (c) substance dependent never smokers, and (d) never smokers with no history of substance dependence. Analysis revealed a main effect of substance use disorder status, such that individuals who were dependent on substances other than nicotine achieved lower net scores on the Gambling Task than those with no history of substance dependence ($p = .05$). A significant sex by substance use disorder status interaction was also identified ($p = .01$). Unexpectedly, no differences in Gambling Task performance were found between smokers and non-smokers. However, individuals who smoked and/or were dependent on another substance discounted delayed rewards on the Delay Discounting Task more rapidly than individuals with no history of smoking or other substance dependence (all p's $< .05$), and no differences in the performance of heavy smokers and substance-dependent individuals were found. Overall, findings indicate that smoking status may impact performance on the Delay Discounting Task, but does not impact Gambling Task performance. Although no sex differences in performance were identified on the Delayed Discounting Task, performance on the Gambling Task differed between men and women.

Introduction

The prevalence of substance use disorders (SUDs) remains high in the United States (U.S.). In a recent review of 19 prevalence studies, it was estimated that the lifetime prevalence of alcohol and other SUDs was 13.2% and 2.4%, respectively (Somers, Goldner, Waraich, & Hsu, 2004). In addition, approximately 21% of adults in the U.S. report current smoking (CDC, 2005). Further, individuals who abuse alcohol or other substances are more likely than those without SUDs to be smokers (Kalman, Morissette, & George, 2005; SAMHSA, 2005).

The personal and social consequences of SUDs are considerable. On average, those with a SUD have more health problems and are less productive on the job than those without a SUD (Harwood, 2000). Nearly one half of all traffic deaths involve either an intoxicated driver or pedestrian (Smith, Branas, & Miller, 1999). Substance dependent individuals are at much greater risk of suicide than those in the general population (American Psychiatric Association, 2000). Further, women who abuse substances during pregnancy may deliver babies who are dependent on substances. Unfortunately, these children may suffer lifelong consequences as a result (CDC, 2004; NIDA, 2004).

Although SUDs are among the most prevalent psychological disorders, treatments for these disorders have not been as efficacious as treatments for many other disorders (Project MATCH Research Group, 1997). A better understanding of the factors that contribute to the development and maintenance of SUDs is needed in order to improve the efficacy of treatment interventions. Further, knowledge of the differences between those who are and are not substance dependent will be important when designing new treatments or improving upon current treatments.

Structural and Functional Brain Abnormalities in Individuals Who Abuse Substances

Several studies have detected structural abnormalities in the brains of those who abuse substances. Liu, Matochik, Cadet, and London (1998) found that the prefrontal cortices of

individuals who abuse multiple substances were comparatively smaller than those of controls who did not abuse substances. Harper and Kril (1990) found that alcohol dependent individuals had less gray matter in their frontal lobes than individuals who were not alcohol dependent. Although the origin of these structural abnormalities is not completely clear, several hypotheses have been suggested. First, there is substantial evidence that alcohol dependence is heritable, and that children of alcohol dependent individuals may inherit a genetic vulnerability to the development of the disorder (Bohman, Cloninger, Sigvardsson, & von-Knorring, 1987). Wiers, Sergeant, and Gunning (1994) have suggested that this vulnerability may be related to congenital brain defects in the prefrontal cortex. Second, neuropathological studies have suggested that repeated exposure to substances of abuse may result in the atrophy of neurons in the prefrontal cortex (Harper & Kril, 1990). Collectively, these studies suggest that congenital defects and/or atrophy of neurons in the prefrontal cortex may be related to the structural brain abnormalities found in substance abusers.

Positron Emission Tomography (PET) and Single-Photon Computed Tomography (SPECT) scans of the brains of individuals who abuse cocaine have suggested that there may be decreased cerebral blood flow in the prefrontal cortices of these individuals (Tumeh, Nagel, English, Moore, & Holman, 1990; Volkow, Mullani, Gould, Adler, & Krajewski, 1988; Weber et al., 1993). Volkow et al. (1992) found that dose and number of years of cocaine use was positively correlated with reduced cerebral blood flow in the frontal cortices of cocaine abusers and this reduction in blood flow remained for up to four months after cocaine use terminated. Individuals who abuse cocaine have also been shown to exhibit differences in metabolic activity in their orbitofrontal cortex when compared with matched controls (Volkow et al., 1991). Similar abnormalities have been detected in individuals who are alcohol dependent (Hommer et al., 1997; Volkow & Fowler, 1992). Overall, findings suggest that the repeated

use of alcohol and cocaine is associated with changes in brain function and these changes are especially notable in the prefrontal cortex.

A reduction in the amount of some neurotransmitters in the prefrontal cortexes of intoxicated humans and other animals has also been found. Chronic administration of amphetamine and methamphetamine has been shown to decrease monoamine levels in the prefrontal cortexes of non-human primates and rats (Seiden & Ricaurte, 1987; Villemagne et al., 1998). Postmortem examinations of the brains of chronic cocaine users have revealed abnormally low levels of dopamine in the orbitofrontal cortex (Wilson et al., 1996).

In summary, studies of the brains of individuals with SUDs have revealed structural and functional abnormalities. It is not clear if these abnormalities predispose individuals to develop SUDs or if repeated substance use results in the alteration of the structure and function of the prefrontal cortex. Prospective studies that examine the brains of individuals both before and after they develop a SUD are needed to determine the causal nature of these factors.

The Ventromedial Prefrontal Cortex (VPC)

The VPC, a specific area of the prefrontal cortex, has been implicated in planning and decision-making tasks. Damage to the VPC has been shown to result in impairment of the ability to extinguish previously rewarded behavior (Rolls, 2000; Rosenkilde, 1979). Individuals with lesions in this area of the brain do not appear to fully consider the future impact of their decisions, and seem to make decisions based in large part on the immediate consequences (Bechara, Damasio, Damasio, & Anderson, 1994; Damasio, 1996; Lyvers, 2000).

Bechara and colleagues (2001) noted that patients with VPC lesions and individuals with SUDs "(1) often deny, or they are not aware, that they have a problem; (2) when faced with the choice to pursue a course of action that brings an immediate reward, at the risk of incurring future negative consequences, including the loss of reputation, job, home, and family

they choose the immediate reward and ignore the future consequences." Although most individuals with SUDs do not have detectable lesions in their VPC, the repeated use of substances may short-circuit the functioning of the VPC, resulting in behavior that is similar to that of VPC lesioned individuals (Lyvers, 2000; Volkow, Fowler, & Wang, 2003). Individuals with SUDs may not accurately weigh the severity of the negative consequences that may follow drug use, and they may therefore decide to use despite the possibility of incurring these consequences (Bartzokis et al., 2000; Bechara et al., 2001; Bechara, Dolan, & Hindes, 2002; Grant, Contoreggi, & London, 2000; Petry, Bickel, & Arnett, 1998). VPC dysfunction may impair the ability of a substance dependent individual to inhibit previously reinforcing behaviors and to intuit future consequences of their behavior (Petry et al., 1998).

The Gambling Task and VPC Lesions

The Gambling Task (GT) was developed to measure decision-making deficits in individuals with lesions in the VPC. This task was designed to parallel real life decision-making involving choice, rewards, and negative consequences for specific behaviors (Bechara et al., 1994; Bechara, Tranel, & Damasio, 2000). In the computerized version of this task, participants sit in front of a computer and pick cards from four decks (Bechara, et al., 2000). Participants earn play money with each card picked and occasionally suffer monetary losses. Some of the decks are advantageous because participants will gain play money overall when they choose cards from these decks. Conversely, some decks are disadvantageous because the participants will lose more play money than is gained when they choose cards from these decks.

The link between GT performance and VPC activity has been demonstrated in several studies. Research studies utilizing PET scans have demonstrated increased activity in the VPC of individuals completing the GT (Bechara et al., 2000; Ernst et al., 2002; Grant, Bonson, Contoreggi, & London, 1999). Bechara et al. (1994) showed that individuals with VPC lesions

were more likely than controls without such lesions, to select cards that yielded large, immediate rewards and very large delayed punishers. Thus, individuals with VPC lesions were more likely to incur a net loss of play money. The relatively poor GT performance of individuals with VPC lesions has been consistently demonstrated (e.g., Bechara, Damasio, Tranel, & Damasio, 1997; Bechara et al., 2001; Bechara et al., 2000).

Research findings suggest that the poor GT performance of individuals with VPC lesions is not due to a generalized dysfunction across the entirety of the prefrontal cortex. Although individuals with VPC lesions tend to perform poorly on decision-making tasks, they do not perform poorly on tasks that are sensitive to lesions in adjacent brain regions (Bechara et al., 1994; Bechara et al., 1997; Bechara et al., 2001; Bechara et al., 2000). Bechara, Damasio, Tranel, and Anderson (1998) reported that individuals with lesions in the dorsolateral prefrontal cortex (an area found to be important to working memory) performed similarly on the GT to controls without such brain lesions, while all individuals with VPC lesions performed poorly on the GT.

Several hypotheses about the reasons for decision-making impairments seen in those with VPC lesions have been explored. Bechara et al. (2000) conducted an experiment to determine whether individuals with lesions in the VPC were impaired on the GT due to a lack of concern for the future consequences of their behavior. Three possible causes of this decision-making impairment were examined: (1) the individual is oversensitive to rewards, (2) the individual is not sensitive to punishment, or (3) the individual is insensitive to the future consequences of his/her behavior, positive and negative. By manipulating the size of the immediate and delayed reinforcers and punishers on the GT, Bechara et al. (2000) showed that individuals with VPC lesions were more focused on the immediate consequences of their choices and largely oblivious to future positive and negative consequences of their behavior.

Performance on the GT by Individuals with SUDs

Studies have indicated that individuals who abuse substances may possess impairments that are similar to those present in individuals with VPC lesions. Bechara et al. (2001) compared the performance of three groups of subjects on the GT. The first group included individuals with VPC lesions, the second group included individuals who were dependent on alcohol, cocaine, or amphetamine, and the third group included individuals with no history of a SUD. The authors found that the performance of substance dependent individuals on the GT was similar to the performance of individuals with VPC lesions, and the control group performed significantly better than the other two groups. Bechara and Damasio (2002) replicated these findings with similar groups of participants. These authors suggested that substance abusers and individuals with VPC lesions may perform similarly on the GT due to a shared defect in the VPC.

Studies of the GT have demonstrated sensitivity to a specific type of impairment that cannot be explained by other cognitive abilities, demographics, or psychopathology. Bechara et al. (2001) tested the hypothesis that neuropsychological tests of cognitive ability, other than the GT, might account for the decision-making impairments seen in individuals who are dependent on cocaine, amphetamine, or alcohol. The Wisconsin Card Sorting Task (WCST), the Tower of Hanoi, and the Stroop test were administered along with a measure of intelligence. Factors including demographics, comorbid depression, anxiety, and other psychopathology were also examined as possible causes of impaired performance on the GT. Results indicated that demographic variables, neuropsychological tests, and psychopathology did not account for the impaired GT performance of individuals with VPC lesions or SUDs. Grant et al. (2000) administered the GT and the WCST to individuals with a history of opioid or stimulant abuse and to a control group with no history of a SUD. Grant et al. (2000) found that substance abusers scored significantly worse on the GT than individuals without a history

of substance abuse. However, no differences were found in the WCST scores of those who abused and did not abuse substances.

It is not clear whether decision-making deficits improve following abstinence from substance use. One study found that recently abstinent cocaine-dependent men (RA) performed better on the GT than cocaine-dependent men who were not abstinent (NA; Bartzokis et al., 2000). The authors administered several neuropsychological tests including the WCST, the California Verbal Learning Test (CVLT), and the GT to determine whether differences in performance on any of these tasks could be detected following a period of abstinence from cocaine. The authors found that the NA group exhibited impaired performance on the GT, while the RA group was not impaired on any of the tasks. Another study found that the GT performance of a group of recently abstinent polysubstance dependent individuals was not significantly different from the GT performance of individuals without a history of a SUD (Fishbein et al., 2005). One interpretation of these findings is that the decision making impairments related to cocaine or polysubstance dependence may be reversible upon abstinence from substance use (Bartzokis et al., 2000; Fishbein et al., 2005).

Other studies have found that recently abstinent substance dependent individuals performed poorly on the GT. Fein, Klein, and Finn (2004) found that alcohol dependent individuals who achieved at least six months of continuous abstinence performed more poorly on the GT than controls without a history of SUDs. Bolla, Eldreth, Matochik, and Cadet (2005) showed that abstinent marijuana dependent individuals performed more poorly on the GT than controls without a history of SUDs. Further research is needed to clarify the effect of abstinence from substance use on GT performance.

In summary, studies have shown that individuals who abuse substances (i.e., cocaine, heroin, alcohol, methamphetamine, and marijuana) perform more poorly on the GT compared to controls with no history of substance abuse. Most of these studies show that individuals

without a history of SUDs learn to choose cards from the advantageous decks, while individuals with SUDs do not learn this strategy (Bartzokis et al., 2000; Bechara et al., 2001; Bechara & Damasio, 2002; Bechara & Martin, 2004; Bolla et al., 2005; Fein et al., 2004; Monterosso, Ehrman, Napier, O'Brien, & Childress, 2001; Petry et al., 1998). Some studies have shown that individuals who abuse substances actually prefer the disadvantageous decks (Bartzokis et al., 2000; Grant et al., 2000; Whitlow et al., 2004). Researchers have suggested that the pattern of responding of individuals who abuse substances on the GT may be evidence of a heightened sensitivity to reward (Bechara et al., 2001; Bechara & Damasio, 2002; Bechara et al., 2002; Finn, Mazas, Justus, & Steinmetz, 2002; Stout, Rock, Campbell, Busemeyer, & Finn, 2005), and attenuated sensitivity to the future consequences (positive and negative) of their actions (Bechara et al., 2000; Petry et al., 1998).

Smokers' Performance on the GT

Despite the relatively high prevalence of cigarette smoking compared with the prevalence of other substance use, only four studies have examined the GT performance of smokers and non-smokers (Businelle, Kendzor, Patterson, Rash, & Copeland, 2004; Harmsen, Bischof, Brooks, Hohagen, & Rumpf, 2006; Lejuez, Aklin, & Jones, 2003; Rotheram-Fuller, Shoptaw, Berman, & London, 2004). Lejuez et al. (2003) administered the GT to two groups of undergraduate college students. One group included individuals who reported that they had never smoked daily. The other group included individuals who reported smoking at least one cigarette per day during the past six months. In contrast with other studies using drug and alcohol dependent samples, no differences in GT performance were found between these groups. One possible reason for the null findings is that the smoking group may have included individuals who were lower in nicotine-dependence. It has been demonstrated that, on average, college students smoke fewer cigarettes per day than individuals in the general population of

smokers (SAMSHA, 2003). Moreover, the comparison group may have included individuals who smoked regularly, but did not engage in daily smoking.

Rotheram-Fuller et al. (2004) compared the GT performance of methadone-maintained heavy smokers, methadone-maintained non-smokers, heavy smokers (not opiate dependent), and non-smokers (not opiate dependent). They found that methadone-maintained heavy smokers performed more poorly on the GT than smokers and non-smokers who were not opiate-dependent. Among methadone-maintained individuals, individuals who smoked performed more poorly on the GT than non-smokers. These findings suggest that individuals who use opiates and nicotine may have more impaired decision-making than individuals who use only one or neither of these substances. Unfortunately, the small sample size and opiate-dependent population utilized in this study limits conclusions about the performance of smokers and non-smokers in general.

Businelle et al. (2004) compared the GT performance of heavy smokers and never smokers. The group of heavy smokers included individuals who smoked a minimum of 20 cigarettes per day for at least 10 years while the never smoker group included individuals who had never smoked cigarettes. Results indicated that individuals with no history of smoking gradually demonstrated a preference for cards from the advantageous decks as the task progressed, but the heavy smokers demonstrated no deck preferences throughout the GT. The authors noted that the results of this study were limited because individuals in the heavy smoker group had higher scores than never smokers on two alcohol and drug abuse screening measures.

Harmsen et al. (2006) examined the GT performance of two groups of daily smokers, those who were nicotine dependent and those who were not dependent on nicotine. Nicotine dependence was diagnosed according to the criteria laid out by the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (American Psychiatric Association, 2000).

Although the groups did not significantly differ on GT performance, it is notable that both groups performed poorly on the GT. Individuals in both groups earned scores similar to the scores earned by individuals in previous studies who were dependent on other substances (Bartzokis et al., 2000; Bechara et al., 2001; Fein et al., 2004). Although a sample of individuals who were not dependent on nicotine or other substances was not recruited for the study, the authors noted that the smokers performed more poorly than the control groups recruited for other studies.

Previous studies that have examined the GT performance of individuals with SUDs have not controlled for smoking status, therefore it is not clear whether poorer performance on the GT was due to cigarette smoking, other substance use, or a combination of substances. It is possible that a history of heavy cigarette smoking mediates and/or moderates the effects of other substance use on GT performance. Studies that compare individuals who smoke, but do not have another SUD and non-smoking individuals with a SUD are needed to determine the relative impact of smoking and other substance use on decision-making task performance.

Sex and GT Performance

Although most of the studies that have examined GT performance among individuals who abuse substances have either excluded women altogether or have failed to examine sex effects, several studies have addressed this issue. Reavis and Overman (2001) found that men without a history of a SUD performed better on the GT than women who were matched on demographic variables. Fein et al. (2004) examined the GT performance of alcohol dependent men and women who had maintained abstinence from alcohol for at least six months. Results showed that women tended to perform better than men, regardless of group. Bechara and Martin (2004) found that women with no history of a SUD performed worse than men with no SUD history, but men and women with SUD histories performed equally poorly on the GT. Stout et al. (2005) compared the GT performance of men and women who abused substances

with the performance of individuals who did not abuse substances. The authors did not find a significant main effect of sex. However, they did find a significant sex by substance abuse interaction such that, the men who abused substances performed worse on the GT than the men who did not abuse substances. Conversely, the women who abused substances performed significantly better on the GT than the women who did not abuse substances. More research is needed to clarify the impact of sex on GT performance.

The Delay Discounting Task

Research studies have suggested that impulsivity may be related to the development and maintenance of SUDs. Impulsivity has been conceptualized as the degree to which individuals discount delayed rewards (Green, Fry, & Myerson, 1994). In the Delay Discounting Task (DDT; Petry & Casarella, 1999), a behavioral measure of impulsivity, an individual is asked to choose between a smaller immediate reward and a larger reward to be given at a specified time in the future. Given this choice, most individuals will choose to receive the larger reward over a smaller reward (Ainslie & Haendel, 1983). However, increasing the amount of time before the larger reward can be received tends to decrease the subjective value of that reward (Ainslie & Haendel, 1983). For example, an individual may be asked whether he or she would prefer $5.00 or $20.00. Most individuals would choose the $20.00 option if both options are immediately available. However, if the individual were asked to choose between $5.00 now and $20.00 in a year, many individuals would choose to receive the $5.00 payment. In this example, the individual decided that the additional $15.00 available after the delay was not worth the wait.

In the DDT, the size of the immediate reward and the amount of time before the delayed reward can be obtained are varied. As the delay to obtain the larger reward increases, the number of individuals who choose the immediate reward increases (Petry & Casarella, 1999). Individuals who shift from preferring the larger delayed reward to the smaller

immediate reward with relatively short delays are considered to be more impulsive than individuals who only prefer the smaller reward with longer delays. An individual's preference for the immediate or delayed reward is tracked across several periods of delay (e.g., one day, one year). The point at which an individual shifts his or her preference from the immediate reward to the delayed reward is termed an indifference point. The indifference point is conceptualized as the point at which a smaller immediately available reward is equal in subjective value to a larger delayed reward.

Bickel and Marsch (2001) examined the contribution of delay discounting to the impulsivity and loss of control that is often evident in individuals who abuse substances. They suggested that delay discounting might account for both the tendency to respond impulsively and the subjective "loss of control" experienced by this group. The authors suggested that individuals who abuse substances might be considered impulsive when a smaller, immediate reinforcer (i.e., drugs) becomes more important than a larger, delayed reinforcer. They defined "loss of control" as "a shift in preference over time from the larger delayed reward to a smaller more immediate reward." For example, when an individual who abuses drugs attempts to quit or decrease their level of drug consumption, he or she chooses a delayed, larger reward (e.g., abstinence, better health) over a smaller, more immediate reward (e.g., high from drugs). When the individual relapses or uses more than he or she intended, he or she has reverted back to choosing smaller, more immediate rewards over the larger, delayed rewards.

Research has indicated that individuals who abuse substances frequently choose smaller, immediate rewards over larger delayed rewards compared to individuals who do not abuse substances. Research has shown that opiate dependent individuals are more likely to discount both real and imagined delayed rewards, such as heroin or money, than individuals without a history of opiate dependence (Kirby, Petry, & Bickel, 1999; Madden, Bickel, & Jacobs, 1999; Madden, Petry, Badger, & Bickel, 1997). Similarly, it has been shown that heavy

drinkers are more likely to discount delayed rewards than light drinkers (Petry, 2001; Vuchinich & Simpson, 1998), and cocaine dependent individuals discount delayed rewards more rapidly than non-dependent controls (Coffey, Gudleski, Saladin, & Brady, 2003). Further, studies have shown that heterogeneous groups of substance abusers more rapidly discount delayed rewards than individuals without a history of substance abuse (Ainslie & Haendel, 1983; Bretteville-Jensen, 1999). Finally, several studies have indicated that the subjective value of delayed rewards is more quickly diminished in current smokers than in nonsmokers (Baker, Johnson, & Bickel, 2003; Bickel, Odum, & Madden, 1999; Kirby & Petry, 2004; Mitchell, 1999; Reynolds, Richards, Horn, & Karraker, 2004).

There is some evidence that the rate at which individuals discount delayed rewards may decrease following abstinence from cigarettes, intravenous drugs use, and alcohol (Bickel et al., 1999; Bretteville-Jensen, 1999; Petry, 2001). However, the decreased rate of delay discounting in recently abstinent individuals who have abused substances must be interpreted cautiously due to cross-sectional study designs. Bickel and Johnson (2003) suggested that there are at least two possible explanations for the decreased discounting rates often seen in abstaining substance abusers. First, it is possible that there were selection biases in studies that used currently abstinent individuals with a history of SUDs (Petry, 2001). Such individuals may have been less likely to discount delayed rewards before they became abstinent, which may have made abstinence easier to achieve. Second, it is possible that the rate of delay discounting varies with the amount of the substance used. As a result, abstinence from substance use may produce discounting rates that mimic those of individuals without a SUD history. In support of this explanation, Reynolds (2004) showed that younger smokers tended to discount delayed rewards to a lesser extent than did adult smokers, and that higher smoking rates were positively correlated with more discounting of delayed rewards. Similarly,

Vuchinich and Simpson (1998) showed that heavier drinkers discounted delayed rewards to a greater extent than light drinkers, regardless of number of years of drinking experience.

Sex and DDT Performance

The findings of studies comparing the performance of men and women who abuse substances on the DDT have been equivocal. At least two studies have found that men discounted delayed rewards more rapidly than women (Kirby & Marakovic, 1996; Kirby & Petry, 2004), while other studies have shown no sex differences in DDT performance (e.g., Kollins, 2003; Logue & Anderson, 2001; Vuchinich & Simpson, 1998). More research is needed to determine the impact of sex on the DDT among individuals who abuse substances.

Summary

The GT and the DDT have demonstrated sensitivity to impaired decision-making among individuals who abuse substances. However, studies that have used these measures have not taken into consideration the high comorbidity between heavy smoking and other substance abuse. It is possible that smoking may contribute to the decision-making deficits observed among those with SUDs. Further research is needed to examine the relative contribution of heavy smoking and other substance dependence on poor GT and DDT performance.

Hypotheses

The purpose of the present study was to examine the performance of four groups of individuals on the GT and the DDT. It was hypothesized that heavy smokers who were dependent on another substance would achieve significantly lower net scores on the GT and discount delayed rewards on the DDT more rapidly than individuals with one or neither type of SUD. Second, it was hypothesized that the GT and DDT performance of heavy smokers without a history of another SUD would be similar to the performance of individuals with a SUD and no history of smoking. Third, it was hypothesized that those without a history of a

SUD (including nicotine dependence) would perform better on both tasks than all other groups. In other words, we expected heavy smokers with a comorbid SUD to perform the worst on both the GT and DDT, followed by the smoker only and SUD only groups, followed by the group of individuals who were nonsmokers with no SUD history. Finally, it was expected that men and women would not significantly differ on GT or DDT performance.

Method

Participants

A total of 117 participants participated in the present study. Participants were recruited through fliers and newspaper advertisements at four facilities: (1) Louisiana State University (LSU), (2) the Capital Area Recovery Program (CARP) in Baton Rouge, Louisiana, (3) the Capital Area Centers for Addictive Disorders (CACAD) in Baton Rouge, Louisiana, and (4) the University of Mississippi Medical Center (UMMC) in Jackson, Mississippi. Individuals were categorized into one of the following groups: (a) heavy smokers with another SUD (n = 36); (b) heavy smokers without another SUD (n = 20); (c) never smokers with a SUD (n = 27); and (d) never smokers without a SUD (n = 34). The study design is depicted graphically in Figure 1. All participants were at least 25 years of age and had at least an eighth grade education. Participants were paid $15.00 to $25.00 for participating in the study. Subject payment was increased from $15.00 to $25.00 in an attempt to boost recruitment near the end of the data collection period.

		Smoking Status	
		Yes	No
Drug and Alcohol Dependence Status	Yes	Smoker plus SUD	SUD only
	No	Smoker only	Neither smoker nor SUD

Figure 1. Study Design. SUD = Substance Use Disorder.

Participants met inclusion criteria for the "heavy smoker" groups if they reported smoking at least 20 cigarettes per day and had been smoking for at least eight years. Participants were included in the "never smoker" groups if they reported smoking ten or fewer cigarettes in their lifetime. Individuals who met criteria for a SUD other than Nicotine

Dependence within the last six months, as assessed by the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID), were placed in the "substance use disorder" groups. Individuals who had no previous history of a SUD other than Nicotine Dependence met criteria for the "no history of substance use disorder" groups. Individuals who had recovered from a previous SUD and those who had quit smoking were excluded from participating in this study.

Measures

Study Screening Questionnaire (SSQ). This questionnaire included questions related to demographic characteristics such as age, sex, education, income, and race/ethnicity. Additionally, this measure inquired about the amount and frequency of past and present substance use (i.e., alcohol, cigarettes, cocaine, opiates, marijuana, amphetamines, and sedatives).

The Fagerström Test for Nicotine Dependence (FTND). The FTND (Heatherton, Kozlowski, Frecker, & Fagerström, 1991) was administered to assess level of nicotine dependence within the heavy smoker groups. The measure contains six items that are related to cigarette use. The FTND has adequate internal consistency and there is evidence of predictive validity (Kozlowski, Porter, Orleans, Pope, & Heatherton, 1994). A score of four or greater has been used as an indicator of nicotine dependence and a score greater than six suggests heavy nicotine dependence (Fagerström, Heatherton, & Kozlowski, 1990; Fagerström et al., 1996).

Expired Carbon Monoxide (CO). Expired CO levels were assessed with a Vitalograph portable CO monitor (Vitalograph Incorporated, Lenexa, KS, USA) in order to verify self-reported smoking status. A minimum CO level of 10 parts per million (ppm) was required of heavy smokers and a CO level of $\leq$ 5 ppm was required of never smokers to participate in the study.

Breath Alcohol Content (BAC). Expired BAC was measured using an Alcohawk Series Digital Breathalyzer (Advanced Safety Devices, Chatsworth, CA, USA). This device has been

approved by the Food and Drug Administration for measuring alcohol intoxication. The presence of any amount of alcohol in the expired breath of a participant (i.e., a reading of ≥ .001%) precluded participation in this study. None of the participants that were screened for this study obtained a positive BAC reading.

Substance Abuse Subtle Screening Inventory, Third Edition (SASSI-3). The SASSI-3 (Miller, 1997) is a self-report questionnaire that consists of 10 subscales designed to evaluate the probability that an individual has a SUD. The SASSI-3 was used to verify the self-reported SUD status of each participant. The SASSI-3 has a test-retest reliability coefficient that ranges from .92 to 1.0 and the measure correlates highly with other measures of substance abuse. The SASSI-3 has a sensitivity of .94 and specificity of .93 for detecting alcohol and drug use disorders (Miller, 1997).

Structured Clinical Interview for DSM-IV Axis I Disorders (SCID). In order to determine whether prospective participants were alcohol or drug dependent, the SUD sections of the SCID (Kranzler, Kadden, Babor, Tennen, & Rounsaville, 1996) were administered to every participant for each drug that the individual reported using in their lifetime. The SCID has proven to be a valid and reliable measure for diagnosing SUDs (Kranzler et al., 1996). Further, the interrater reliability for a diagnosis of alcohol dependence is .96 and the interrater reliability for a diagnosis of drug dependence is .85 (Kranzler et al., 1996).

The SCID and SASSI-3 were in agreement for SUD diagnoses 99% of the time. One individual denied current and past substance use problems when interviewed with the SCID, but later reported cocaine dependence after the SASSI-3 indicated a probable SUD. This individual was allowed to continue in the study, but was moved from the heavy smoker without another SUD group to the heavy smoker with another SUD group.

The Computerized Version of the Gambling Task (GT). The GT was administered to measure participants' ability to evaluate potential immediate gains and long-term losses

according to the protocol established by Bechara et al. (2000). During the task, participants were seated in front of a computer screen on which there were four decks of cards. The participant was prompted to use the mouse to pick a card from one of the decks labeled A', B', C', and D'. After picking a card, the computer made a distinct sound (i.e., a high-pitched tone for wins and a low-pitched tone for losses) and the individual was informed of the amount of money won and lost during that trial. The participant won money with every card picked. After some card picks, the individual was informed that he or she won money and also lost money. The amount of monetary wins and the amount and frequency of losses were different for each deck according the schedule described below.

Decks A' and B' paid $100 on average, while decks C' and D' paid an average of only $50. However, decks A' and B' yielded greater penalties than decks C' and D'. Taking into account rewards and penalties, picking from decks A' or B' yielded a net loss of $250 for the first 10-card block. The net loss for picking cards from decks A' or B' increased by $150 for every 10-card block until block six, where the net loss was $1,000. In deck A', the average monetary loss was constant and the frequency of monetary loss increased as the task progressed. In deck B', the frequency of loss was constant and the amount of loss increased as the task progressed (Bechara et al., 2001). For the purposes of this study, decks A' and B' are termed "disadvantageous decks" and cards from these decks are termed "disadvantageous cards," because choosing cards from these decks resulted in cumulative net losses in play money.

Picking from decks C' or D' yielded a net gain of $250 for the first 10-card block. The net gain for that came with picking cards from decks C' and D' increased by $25 for each 10-card block until block six when the net gain was $375. In deck C', the average amount of the monetary loss was constant and the frequency of losses increased as the task progressed. In deck D', the amount of monetary loss increased but the frequency of loss was constant

(Bechara et al., 2001). For the purposes of this study, decks C' and D' are referred to as "advantageous decks" and cards from these decks are referred to as "advantageous cards," because choosing cards from these decks resulted in cumulative net gains in play money.

Participants were instructed to win as much play money as possible. Consistent with the procedure of Bechara et al. (2001), the participants picked a total of 100 cards and the intertrial interval between card picks was set at six seconds. The total score on the GT was calculated by summing the number of cards chosen from the "advantageous decks" (decks C' and D') and subtracting the number of cards selected from the "disadvantageous decks" (decks A' and B').

Monterosso and colleagues (2001) showed that using only the last 50 trials on the Gambling Task is a more reliable measure of performance than using all 100 trials. They reasoned that, during the first 50 trials, the participants are learning the reward and punishment schedules. Therefore, if all 100 trials were to be counted, participants' scores could be inflated or deflated, depending on the strategy the participant took in learning the task. Following the suggestion of Monterosso et al. (2001), this alternate scoring method was also used to examine GT performance.

Delay Discounting Task (DDT). In the DDT (Petry & Casarella, 1999) procedure, participants were asked whether they would prefer a smaller sum of hypothetical money immediately or a larger sum of hypothetical money at some point in the future. Index cards with printed monetary amounts were placed in front of the participant and the participant chose which card he/she preferred. Each index card had one of the following monetary amounts written on it: $1000, $999, $995, $990, $960, $940, $920, $850, $800, $750, $700, $650, $600, $550, $500, $450, $400, $350, $300, $250, $200, $150, $100, $80, $60, $40, $20, $10, $5, and $1 (Petry & Casarella, 1999). On each successive trial, participants were asked if they would prefer the amount written on one of the index cards to be given immediately or $1000 (written

on another index card) after some delay. The task continued until the participant chose between each of the previously specified monetary amounts and $1000.

After the task was completed for one time delay, the procedure was continued for the next time delay. The delay intervals were as follows: 6 hours, 1 day, 1 week, 2 months, 6 months, 1 year, 5 years, and 25 years. The points at which the individual switched from preferring the immediate amount to the delayed amount were noted and the previous trial was recorded as an indifference point. Following Petry and Casarella (1999), instructions were read to each participant before the task began.

Mazur's (1987) equation was used to derive discounting rates: $V = A / (1 + kD)$. V represents the smaller amount of immediately available money that is equal in subjective value to the larger amount of delayed money (i.e., indifference point). A represents the amount of money that is available after the delay. D represents the delay in months and k represents the discounting rate. The GraphPad software package (Motulsky & Christopoulos, 2004) was used to fit these indifference points into the equation above, yielding the best fit discounting rate (i.e., k value) for each participant.

Procedure

Individuals who called the laboratory in response to the flyers and newspaper advertisements were asked for their permission to be questioned about demographic characteristics as well as past and current substance use. Individuals were informed that all of their responses would remain confidential. Potential participants were screened over the telephone to determine eligibility for this study via the SSQ and the SUD portions of the SCID. Individuals seen at CACAD and CARP were screened in person.

Individuals who met the study inclusion criteria based on the phone screening were scheduled for an experimental session on the LSU or UMMC campus and asked abstain from consuming alcohol for 12 hours prior to their appointment. Eligible individuals who were

screened at CACAD and CARP completed the testing session immediately after they were screened if they were interested in participating. The study was described and informed consent was obtained from each participant. Participants were also informed that the National Institute on Drug Abuse had issued a Certificate of Confidentiality for the current project, thus providing an additional protection of participant confidentiality. Participants provided breath samples for CO analysis and BAC in order to verify self-reported smoking status and recent abstinence from alcohol. The FTND, SASSI-3, and DDT were administered. Participants were then given verbal instructions on how to complete the computerized GT. Following completion of all measures, participants were debriefed, thanked for their participation, and paid $15.00 to $25.00.

Results

A total of 455 individuals were screened as potential participants for this study. Two hundred fifty-one of those screened did not meet the study inclusion criteria for a variety of reasons (e.g., age, number of cigarettes smoked per day) and 19 met the inclusion criteria but were not interested in participating. Fifty-one individuals met the inclusion criteria for the study, but did not attend their scheduled testing sessions. Seventeen individuals were not invited to participate because the cell for which they qualified was already full. The remaining 117 individuals completed the study.

Participant Characteristics

Participants were 61.5% Caucasian, 35% African-American, and 3.5% Asian or other. Approximately 54.7% of participants were male. On average, participants were 40.6 ($\pm$10.8) years old and had completed 13.4 ($\pm$2.3) years of education. Participants' average annual income was $21,971 ($\pm$17,637).

Group Comparability

Analyses were conducted to identify differences in demographic variables across the four groups of participants. A Chi-square analysis with sex and smoking/substance status group as the factors indicated that the ratio of males to females was comparable across groups. A second Chi-square analysis with race/ethnicity and smoking/substance group as the factors, revealed that there were significant differences in the racial/ethnic distribution of the groups, $X^2(12, N = 117) = 21.55, p = .04$. Specifically, there were higher than expected proportions of Caucasians in the group of individuals who smoked and had another SUD, and a greater number of African-Americans in the group of never smokers with another SUD. A one-way analysis of variance (ANOVA) showed that the groups were significantly different in years of education, $F(3, 113) = 11.71, p < .001$, such that individuals in the group of never smokers without a SUD completed more years of education than each of the other three groups. A

one-way ANOVA revealed differences in CO levels, $F(3, 113) = 62.78$, $p < .001$, such that the two groups of smokers had higher CO levels than the two never smoker groups. No significant differences were found across groups in age or personal income. Since groups were different in race/ethnicity and years of education, all between-group analyses included these variables as covariates. Participant characteristics for each of the four groups are displayed in Table 1.

Table 1. Participant Characteristics

	Smoker + SUD (n = 36)	Nonsmoker + SUD (n = 20)	Smoker + No SUD (n = 26)	Nonsmoker + No SUD (n = 34)
Age (years)	38.8 ± 7.3	39.7 ± 9.6	43.4 ± 10.5	40.9 ± 14.2
Sex (% male)	58.3	70.0	44.4	50.0
Race/Ethnicity (%)				
Caucasian	80.6	40	59.3	55.9
African-American	19.4	60	33.3	38.2
Asian	0.0	0.0	0.0	5.9
Hispanic	0.0	0.0	3.7	0.0
Other	0.0	0.0	3.7	0.0
Education (years)	12.3 ± 2.1	12.8 ± 1.7	13.2 ± 1.6	15.0 ± 2.3
Annual income	$17,618 ± $17,725	$19,675 ± $11,702	$26,438 ± $21,033	$24,518 ± $17,197
CO	24.0 ± 11.5	1.7 ± 1.5	24.7 ± 13.2	1.0 ± .8
FTND	7.2 ± 1.7	--	5.8 ± 2.2	--
CPD	27.4 ± 8.3	--	23.6 ± 9.2	--
Years smoking	23.3 ± 8.0	--	24.3 ± 12.6	--

Note. CO = carbon monoxide; FTND = Fagerström Test for Nicotine Dependence; CPD = cigarettes per day; SUD = Substance Use Disorder.

One-way ANOVAs were conducted to test for differences between the two groups of smokers in number of cigarettes smoked per day, number of years smoking, and FTND scores. Results indicated that the two groups of smokers did not differ in the number of cigarettes smoked per day or years smoking. Although both groups of smokers appeared to be highly nicotine dependent ($M = 6.57$), the two heavy smoker groups were significantly different in FTND scores, $F(1, 61) = 8.05$, $p < .01$, such that the smokers with another SUD had significantly higher FTND scores than the smokers without another SUD. Table 1 lists means and standard deviations for all smoking related variables.

The groups that included individuals with SUDS were tested for differences in the frequency of SUD diagnoses. A series of Chi-square analyses revealed that the groups were comparable in the proportion of individuals who were dependent on alcohol, marijuana, opiates, hallucinogens, and sedative/hypnotics. However, a larger proportion of the smokers with another SUD were dependent on amphetamines, $X^2(1, N = 55) = 5.35$, $p = .02$, and cocaine, $X^2(1, N = 55) = 6.92$, $p < .01$, than never smokers with a SUD. Table 2 lists the number of individuals within each group who were dependent on each substance.

Table 2. Number of Individuals with Each Type of Substance Dependence

	Total	Smoker + SUD	Smoker + No SUD	*p*
Alcohol	35/55	22/35	13/20	*ns*
Marijuana	23/55	17/35	6/20	*ns*
Cocaine	32/55	25/35	7/20	.008
Amphetamines	8/55	8/35	0/20	.02
Opiates	11/55	8/35	3/20	*ns*
Sedatives	7/55	6/35	1/20	*ns*
Hallucinogen	3/55	3/35	0/20	*ns*

Note. SUD = Substance Use Disorder.

Gambling Task Performance

GT Total Score. To address hypotheses related to the effects of sex, smoking status, and SUD status on GT total score, a 2 X 2 X 2 ANOVA was conducted with smoking status (smoker vs. nonsmoker), SUD status (SUD positive vs. SUD negative) and sex (male vs. female) as the between subjects factors, and total score on the GT as the dependent variable. Race/ethnicity and years of education were entered as covariates. Analysis revealed a significant main effect of SUD status, $F(1, 107) = 2.87$, $p = .05$, one tailed, such that individuals with a SUD ($M = 1.92$) achieved lower net scores on the GT than individuals with no history of a SUD ($M = 12.94$). Additionally, a marginally significant main effect of sex was found, $F(1, 107) = 3.31$, $p = .07$, such that women ($M = 1.94$) earned lower net scores on the GT than men ($M = 12.92$). Unexpectedly, smoking status was not related to GT total score (all p's > .38). Finally, a marginally significant interaction between sex and SUD status was found,

$F(1, 107) = 3.35$, $p = .07$. Specifically, men with a SUD earned lower net scores on the GT than men without a SUD, while women with and without SUDs earned low net scores on the GT. Figure 2 depicts the GT scores of males and females with and without SUDs.

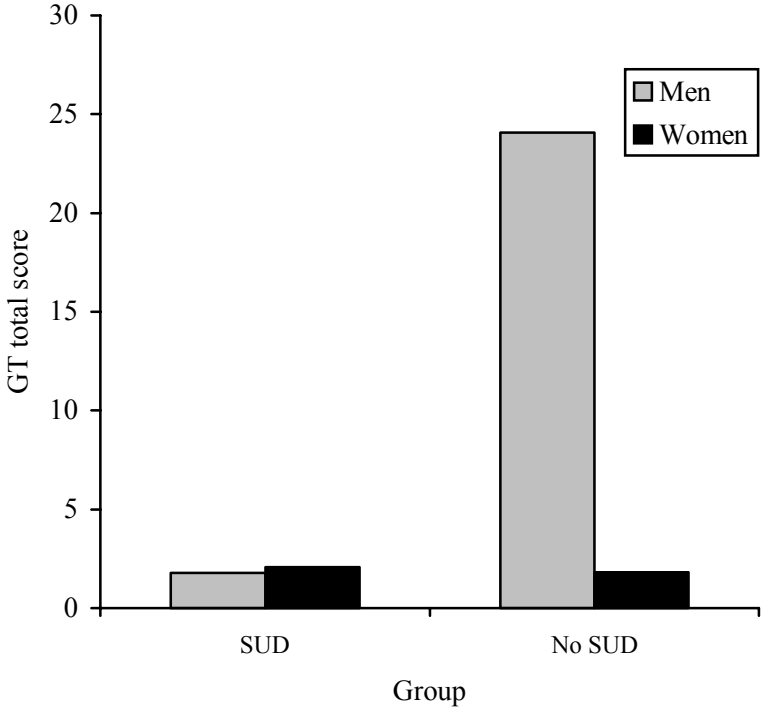

Figure 2. Total score on the Gambling Task by SUD status and sex. SUD = Substance Use Disorder.

GT Score on the Last 50 Card Picks. To address hypotheses related to the effects of sex, smoking status, and SUD status on last 50 card picks on the GT, a 2 X 2 X 2 ANOVA was conducted with smoking status (smoker vs. nonsmoker), SUD status (SUD positive vs. SUD negative) and sex (male vs. female) as the between subjects factors, and score on the last 50 card trials of the GT as the dependent variable. Race/ethnicity and years of education were entered as covariates. No significant main effects of sex, smoking status, or SUD status were found. However, a significant sex by SUD status interaction was revealed, $F(1, 107) = 6.87$, $p = .01$. Men without SUDs achieved higher net scores on the last 50 card trials than men with a SUD, while women without SUDs scored slightly lower than women with SUDs. Figure 3

depicts the scores on the last 50 card trials of the GT for males and females with and without SUDs.

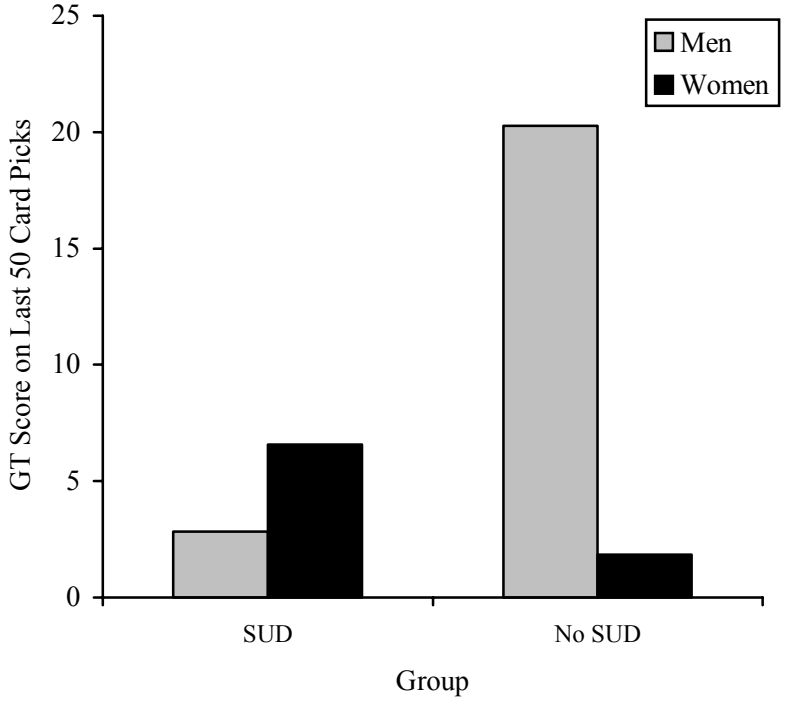

Figure 3. Gambling Task score on the last 50 card picks by SUD status and sex. SUD = Substance Use Disorder; GT = Gambling Task.

Impaired vs. Unimpaired GT Performance. Performance on the GT was also examined by comparing the proportion of individuals of each sex, with and without SUDs, who scored in the impaired range on the GT. A net score of less than 10 on the GT has been suggested as a cutoff for "impaired" performance on this task, given that individuals with VPC lesions rarely achieve net scores above 10 (Bechara et al., 2002; Bechara & Martin, 2004). A Chi-square analysis was conducted with SUD status by sex (males with a SUD, males without a SUD, females with a SUD, and females without a SUD) as one factor and GT performance (impaired vs. not impaired) as the other factor. Results indicated that the groups were significantly different in the proportion of individuals who scored in the impaired range on the GT, $X^2(3, N = 117) = 10.24$, $p = .02$. The highest proportion of individuals who scored in the impaired

range on the GT were women with SUDs, followed by men with SUDs, women without SUDs, and men without SUDs. This pattern of findings was consistent with or without separate consideration of smoking status. See Figure 4 for the percentages of individuals in each group who scored within the impaired range on the GT.

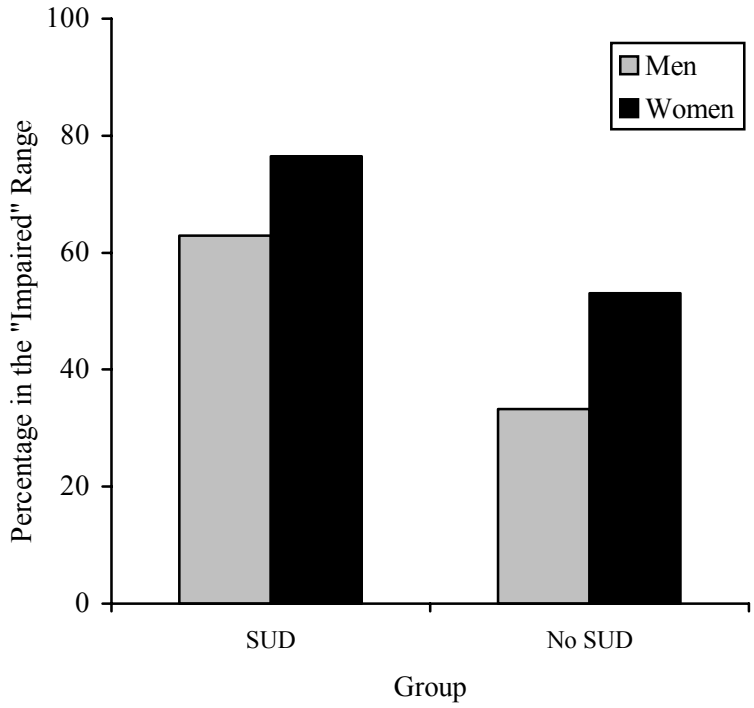

Figure 4. Number of men and women with and without SUDs who scored in the impaired range on the Gambling Task. SUD = Substance Use Disorder.

Delay Discounting Task Performance

An initial 2 X 2 X 2 ANOVA was conducted with SUD status, smoking status, and sex as the factors and log transformed discounting rates (*k* values) as the dependent variable. Similar to other studies, participants' *k* values were transformed to correct for the non-normal distribution of discounting rates within this sample (e.g., Baker et al., 2003; Kirby et al., 1999; Petry, 2001). Race/ethnicity and years of education were included as covariates in the analysis. As hypothesized, sex was not significantly related to DDT performance (all *p*'s > .21).

Therefore, sex was collapsed across all groups and was not considered as a factor in any of the DDT analyses.

In order to examine the relationship between SUD status, smoking status, and DDT performance, a 2 X 2 ANOVA was conducted with SUD status and smoking status as the independent variables and log transformed discounting rates as the dependent variable. Race/ethnicity and years of education were included as covariates in the analyses. Results indicated a significant main effect of smoking status, $F(1, 105) = 5.51$, $p = .01$, one tailed, such that smokers tended to discount delayed rewards more rapidly than never smokers. A marginal main effect of SUD status was also found, $F(1, 105) = 2.54$, $p = .057$, one tailed, such that individuals with SUDs trended toward more rapid discounting of delayed rewards than individuals without a SUD history. However, the interaction between SUD status and smoking status was not significant. See Table 3 for median untransformed *k* and R^2 values for each group.

Table 3. Median Discounting Rates and R^2s on the Delay Discounting Task

Group	Median Discounting Rate *(k* value)	R^2
Smoker + SUD	.0948	.9855
Nonsmoker + SUD	.0828	.9568
Smoker + No SUD	.0805	.9598
Nonsmoker + No SUD	.0362	.9672

Note. SUD = Substance Use Disorder.

Planned comparisons were conducted to test the hypotheses that heavy smokers and individuals with other SUDs would discount delayed rewards more rapidly than those with no history of a SUD and that heavy smokers who were dependent on another substance would discount delayed rewards more rapidly than those with only one or neither of these characteristics. Results revealed that individuals in the never smoker without a SUD group discounted delayed rewards less rapidly than individuals in the heavy smoker with another SUD group ($p = .003$), never smoker with a SUD group ($p = .04$), and heavy smoker without

another SUD group (p = .009). The discounting rates of those who were heavy smokers and/or had another SUD were nearly identical. For example, heavy smokers, individuals with a SUD, and smokers with another SUD discounted half the value of the hypothetical $1000 after just under 11 months, while individuals with no history of smoking or other SUDs were willing to wait over twice as long (i.e., 24 months) before discounting the hypothetical money by fifty percent. No other significant differences were found between groups. Figure 5 depicts the median hyperbolic delay curves for each group of participants.

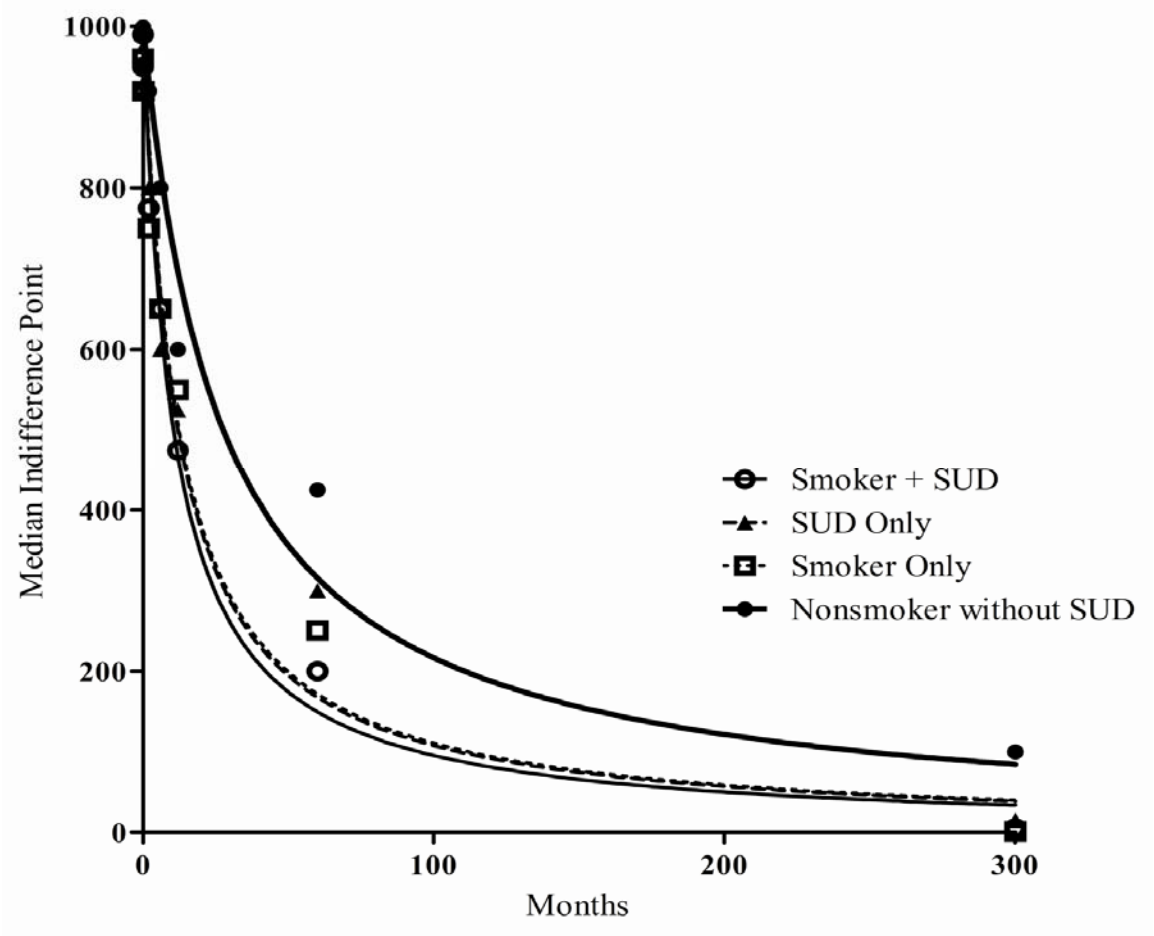

Figure 5. Median indifference points for each period of delay within each of the four groups. Best fit lines were drawn through these points using Mazur's (1987) hyperbolic decay equation. SUD = Substance Use Disorder.

Relationship between the DDT and GT

The relationship between the DDT and GT was examined via Pearson product moment correlations. Results revealed significant correlations between the DDT *k* value and GT total score (r = -.229, p = .02), as well as the DDT *k* value and score on the last 50 card trials of the GT (r = -.232, p = .01). Individuals who discounted delayed rewards more rapidly also tended to have slightly lower GT total scores and slightly lower scores on the last 50 card picks of the GT. Although the GT and DDT were significantly correlated, this correlation was very small, suggesting that these tasks may measure different, but related constructs. These results are consistent with previous findings that the GT and DDT measure similar, but not identical, constructs (Monterosso et al., 2001).

Discussion

Numerous studies have shown that individuals with SUDs perform differently from individuals without SUDs on behavioral measures of risk-taking and preference for immediate rewards (e.g., Bechara et al., 2001; Petry, 2001; Rogers et al., 1999). Research has demonstrated that individuals with SUDs are more willing to risk incurring large losses if a large reward is available and such individuals prefer smaller rewards if larger rewards are only available after a delay. The present study addressed several questions related to the decision-making task performance of individuals with and without SUDs. Specifically, the present study examined the relative impact of smoking versus other SUDs on DDT and GT performance and compared the DDT and GT performance of men and women.

Results indicated that heavy smokers, like individuals with other types of SUDs, discounted delayed rewards on the DDT more rapidly than individuals with no history of a SUD. The discounting rates of individuals with one or both of these problems were nearly identical. It is possible that individuals with any form of SUD, including smoking, may exhibit rapid discounting of delayed rewards and that the addition of another SUD may not have a cumulative impact on DDT performance.

The hypothesis that heavy smokers would earn lower net scores on the GT than individuals without a history of smoking was not supported. Smokers' decision-making in the GT was qualitatively different from that of individuals with most other forms of SUDs. Smokers without another SUD tended to perform similarly to individuals who did not smoke and did not have a SUD. Furthermore, heavy smokers with another SUD performed similarly to individuals with a SUD and no history of smoking. Other factors that are not measured by the GT likely impact smokers' decisions to engage in behavior that may come with considerable long-term consequences. The results of this study suggest that there may be no

need to control for smoking status when examining the GT performance of individuals with other SUDs.

It is not clear why individuals with SUDs performed poorly on the GT while heavy smokers performed similar to controls on this task. Lejuez et al. (2003) suggested that the GT may not be sensitive enough to detect subtle decision-making deficits that may be present in individuals who smoke. However, subtle differences in decision-making and willingness to take risks may prove to be measurable in heavy smokers with other behavioral tasks of delay and risk such as the Balloon Analog Task (Lejuez et al., 2003), the Rogers Decision-Making Task (Rogers et al., 1999), and the DDT (Green et al., 1994).

As hypothesized, no sex differences in DDT performance were identified. This finding is consistent with most of the other studies that have examined the effect of sex on DDT performance (e.g., Kollins, 2003; Logue & Anderson, 2001; Vuchinich & Simpson, 1998). However, the performance of men and women on the GT was significantly different. Men with a SUD chose more cards from the disadvantageous decks than men without a SUD, while women earned low scores on the GT regardless of SUD status. This result is consistent with the findings of at least three other studies and suggests that the GT may not be a valid measure of decision-making in women (Bechara & Martin, 2004; Reavis & Overman, 2001; Stout et al., 2005). The observed differences in the GT performance of men and women without SUDs may reflect the use of different problem-solving strategies while completing the task (Reavis & Overman, 2001). In support of this hypothesis, there is some recent evidence that men and women use different prefrontal regions while completing the GT (Bolla, Eldreth, Matochik, & Cadet, 2004). Future studies should verify sex differences in GT performance in a larger sample of participants, and attempt to identify the reasons for such differences in performance.

Monterosso et al. (2001) showed that the DDT and GT performance of cocaine dependent individuals were weakly correlated, suggesting that these two measures may

measure different, but related constructs. In the current study, GT performance was also weakly related to DDT performance. Individuals who performed better on the GT by selecting more cards from the advantageous decks tended to have slightly lower delay discounting rates, while individuals who chose more cards from the disadvantageous decks tended to have slightly higher delay discounting rates. Although performance on the DDT and GT were slightly correlated, heavy smokers did not perform poorly on both tasks. The performance of heavy smokers on the DDT was similar to individuals with other types of SUDs; however, heavy smokers' performance on the GT was similar to that of individuals with no history of other SUDs.

Limitations

Several limitations of the present study should be noted. The small number of participants within each cell limited the ability to draw conclusions from the findings. Thus, differences between groups, where actually present, may not have been detected due to inadequate power. Further, the two groups of individuals with SUDs contained disproportionate numbers of individuals who were dependent on cocaine and amphetamines. Despite these differences, the SUD groups performed similarly on the GT and DDT, suggesting that these differences may have had a minimal impact on decision-making task performance.

Further, subjects did not receive money based on their choices in the DDT. Rather, they were asked to choose between immediate and delayed amounts of hypothetical money. Willingness to accept smaller amounts of hypothetical money offered immediately versus larger sums of hypothetical money only available after a delay might not accurately reflect the individual's actual decisions if the money were real. However, several studies have shown that the discounting rates for hypothetical money are similar to the discounting rates observed when real money is offered (Johnson & Bickel, 2002; Kirby, 1997; Lagorio & Madden, 2005).

Similarly, participants received the same payment for their participation in the study regardless of their performance on the GT, which may have resulted in poorer performance among unmotivated participants. Future studies should consider offering small bonus payments for high GT scores. This may be a relatively inexpensive way to increase motivation to perform well on this task.

Another limitation of the present study was that the groups differed in years of education and race/ethnicity. Although attempts were made to control for these group differences, it was not possible to control for all variables that differentiate between individuals who are substance dependent and those who are not. Furthermore, decision-making differences and preferences for immediate versus delayed rewards likely play a significant role in the lower education levels often seen in those who smoke heavily and have other SUDs (Whitlow et al., 2004). The pursuit of higher levels of education typically yields relatively infrequent and protracted rewards, and likely requires a greater tolerance for waiting for delayed rewards. It is possible that individuals with SUDs may achieve lower levels of education due to their relative intolerance for delayed rewards.

Finally, with the exception of alcohol and tobacco, we did not biochemically verify the occurrence of recent substance use. Therefore, we cannot be certain that individuals were completely honest about their use of substances. We attempted to reduce the likelihood of missing SUD diagnoses by using multiple methods to detect SUDs (i.e., SASSI-3, SCID). The SUD measures utilized in the present study were in agreement regarding the presence or absence of a SUD in 99% of cases. However, the possibility remains that some individuals misrepresented their SUD history and were therefore inaccurately categorized.

Future Directions

The reasons for the differences in decision-making task performance between substance dependent and non-dependent individuals, has not been thoroughly examined.

Prospective study designs are needed to determine whether: (1) poor performance on tasks of risk and delay is a predisposing factor for the development of SUDs or (2) poor performance on these tasks occurs as a result of substance use. One way to examine this issue would be to utilize a longitudinal study design by administering decision-making tasks to children before they have experience with substance use, and again after some of them have developed a SUD. If poor task performance at the first administration of the task predicts higher incidence of SUDs, then the idea that poor task performance predicts SUD development would be supported. However, if decision-making task performance worsened only after the development of a SUD, the hypothesis that substance use negatively impacts task performance may be more accurate.

Treatment Implications

To date, the impact of treatment for SUDs on decision-making task performance has not been examined. Although studies have demonstrated that abstinence from substance use may increase tolerance for delayed rewards, it is unclear whether treatment or abstinence decreases discounting rates (Bickel et al., 1999; Bretteville-Jensen, 1999; Petry, 2001). Further, high discounting rates before and after the completion of a substance abuse treatment program may be significant predictors of future relapse. Perhaps individuals who successfully complete SUD treatment programs learn skills that enable them to choose delayed rewards (e.g., better health, better family relationships, better job opportunities), despite the continued allure of the immediate rewards associated with substance use. It is possible that incorporating treatment components aimed at improving decision-making, might improve treatment outcomes.

The results of this study may have implications for the treatment of SUDs. Contingency management programs that offer relatively immediate rewards (e.g., vouchers, gift cards) for treatment consistent behaviors have shown great promise in increasing treatment attendance and decreasing drug use among individuals with SUDs (Businelle, Parker, May,

Kendzor, & Burke, in press; Helmus, Saules, Schoener, & Roll, 2003; Higgins et al., 1994; Petry, Martin, Cooney, & Kranzler, 2000; Sinha, Easton, Renee-Aubin, & Carroll, 2003). Adjunctive contingency management treatment may be well suited for the portion of individuals with SUDs who rapidly discount delayed rewards. The provision of immediate reinforcement for treatment consistent behaviors among substance dependent individuals with decision-making deficits may supplement the necessary motivation to maintain abstinence.

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Vita

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