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Impaired decision making as a risk factor for college student drinking

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IMPAIRED DECISION MAKING AS A RISK FACTOR FOR

COLLEGE STUDENT DRINKING

by

Dana Figlock

An Abstract

Of a thesis submitted in partial fulfillment of the
requirements for the Doctor of Philosophy degree
in Psychology (Clinical Psychology) in
the Graduate College of
The University of Iowa

December 2010

Thesis Supervisors: Professor Emeritus Peter E. Nathan
Professor Michael W. O'Hara

ABSTRACT

The primary aim of the present study was to determine whether impairment on neuropsychological measures of decision making predicts increased alcohol use among college students. It was hypothesized that poorer performance on measures of decision making would predict linear increase on indicators of alcohol consumption across the first year of college. An additional aim was to assess whether established risk factors for college student drinking would moderate the association between decision making abilities and increased alcohol consumption, with the expectation that decision making would be more strongly associated with escalation in alcohol use for participants that are male, have a family history of alcohol abuse, report a longer history of pre-college alcohol use, hold more positive alcohol expectancies, and are more impulsive. Aims were pursued in a relatively homogeneous sample of first year college students (N = 136), using a prospective, longitudinal design in which decision making and drinking were assessed at three time-points during the first year of college. Participants additionally provided sociodemographic information and completed self-report impulsivity and alcohol expectancy questionnaires at each assessment. Results showed that drinking and associated negative consequences increased over time during the participants first year in college. However, there was generally little support for the hypotheses that poor decision making abilities are a risk factor for increased alcohol consumption, and that the association is moderated by established risk factors for drinking. Results suggest the need to consider whether drinking is indeed indicative of impaired decision making and underscore the importance of including other factors, especially perceived benefits and influence of social pressure, in models of decision making striving to predict drinking among college students.

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CERTIFICATE OF APPROVAL

PH.D. THESIS

This is to certify that the Ph.D. thesis of

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This dissertation is dedicated to my mom, Carol, who taught me the value of an education, inspired me with her personal strength, provided unconditional love and unwavering support, and believed in me at times when I doubted myself.

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ABSTRACT

The primary aim of the present study was to determine whether impairment on neuropsychological measures of decision making predicts increased alcohol use among college students. It was hypothesized that poorer performance on measures of decision making would predict linear increase on indicators of alcohol consumption across the first year of college. An additional aim was to assess whether established risk factors for college student drinking would moderate the association between decision making abilities and increased alcohol consumption, with the expectation that decision making would be more strongly associated with escalation in alcohol use for participants that are male, have a family history of alcohol abuse, report a longer history of pre-college alcohol use, hold more positive alcohol expectancies, and are more impulsive. Aims were pursued in a relatively homogeneous sample of first year college students (N = 136), using a prospective, longitudinal design in which decision making and drinking were assessed at three time-points during the first year of college. Participants additionally provided sociodemographic information and completed self-report impulsivity and alcohol expectancy questionnaires at each assessment. Results showed that drinking and associated negative consequences increased over time during the participants first year in college. However, there was generally little support for the hypotheses that poor decision making abilities are a risk factor for increased alcohol consumption, and that the association is moderated by established risk factors for drinking. Results suggest the need to consider whether drinking is indeed indicative of impaired decision making and underscore the importance of including other factors, especially perceived benefits and

influence of social pressure, in models of decision making striving to predict drinking among college students.

TABLE OF CONTENTS

LIST OF TABLES

Table

CHAPTER I

INTRODUCTION

It is now well established that persons with long histories of heavy drinking sometimes experience structural and functional changes in the brain, especially in the frontal lobes, that are associated with impaired cognition. Investigations of the causal relationship between alcohol use and cognitive functioning have yielded mixed results because of the evidence for an association between long-term alcohol use and cognitive risk factors that increase the likelihood of alcohol abuse. Recent theories of decision making have been invoked to explain compulsive drinking; they predict that deficits in cognitive ability precede alcohol dependence. Although studies reliably demonstrate that persons with alcohol dependence perform poorly on validated laboratory measures of decision making, temporal precedence has not been established.

Given the prevalence and consequences of heavy drinking among college students, decision making abilities, considered a potential risk factor for drinking in this population, merit assessment. Although a number of empirical studies have sought to identify risk factors for drinking by college students, no studies to date have examined decision making as one such risk factor. The present study seeks to determine whether impairment on neuropsychological measures of decision making predicts alcohol use in college students. This goal was accomplished by utilizing a longitudinal design in which decision making and drinking were assessed at three time-points over the first year of college.

The following review of the literature provides a theoretical basis for the study. It begins with a review of general cognitive impairments associated with substance use, with a focus on whether such deficits presage alcohol use or, instead, are consequences of heavy alcohol use. The cognitive abilities that permit decision making were of particular interest to the present study, so theories of decision making are reviewed. Evidence is presented attesting to the utility of laboratory measures of decision making in persons with substance dependence. Finally, the literature on decision making abilities among binge drinking college students is reviewed; it highlights the need to consider decision making as a risk factor for drinking in this population.

Cognitive Correlates of Alcohol Use

Adults with Alcohol Dependence

Neuropsychological findings. One of the earliest reviews of cognitive functioning in alcoholics concluded that alcoholics perform more poorly than healthy controls on a variety of neuropsychological measures (Kleinknecht & Goldstein, 1972). Studies over the past 30 years have corroborated these findings, consistently demonstrating that chronic, heavy alcohol consumption is associated with concomitant changes in general cognitive functioning (e.g., Bates, Bowden & Barry, 2002; Giancola & Moss, 1998), as evidenced by poorer performance on measures of visuospatial abilities and memory (e.g., Sullivan, Fama, Rosenbloom & Pfefferbaum, 2002; Ratti et al., 1999; Parsons, 1998).

The extent to which alcohol dependence is associated with deficits in the "higher order" cognitive operations known as executive functions, which guide complex behavior through self-direction, delayed gratification, planning, decision-making, and response control, has also been examined (Zinn, Stein, Swartzwelder, 2004; Barkley, 1997). Specific abilities related to executive functioning assessed by neuropsychological measures include attentional control, abstract reasoning, cognitive flexibility, working memory, decision making, and planning (Stuss & Benson, 1984). To the extent that compulsive, pathological drinking is influenced by poor behavioral control and decision making, there should be an association between alcohol dependence and measures of executive functioning such as the Wisconsin Card Sorting Task (Heaton, 1981), Tower of Hanoi (Lezak, 1995), Stroop Test (Stroop, 1935), Trail Making Test (Reitan & Wolfson, 1993), and word-fluency tests (Benton & Hamsher, 1978).

Consistent with expectations, studies have reliably demonstrated that executive functions are often the most severely impaired of all cognitive deficits in alcohol-dependent adults (Giancola & Moss, 1998). Alcoholics have slower processing speed and impaired cognitive flexibility and attentional control as compared to non-alcoholics (Zinn et al. 2004; Ratti, Bo, Giardini & Soragna, 2002; Paraherakis, Charney, & Gill, 2001). They also have difficulty manipulating information in working memory, planning, and inhibiting impulsive behavioral responses (Noel, Bechara, Dan, Hanak & Verbanck, 2007).

Deficits in executive functioning persist after cessation of drinking and have been observed in alcoholics who have been abstinent for several weeks (Bates, Voelbel, Buckman, Labouvie & Barry, 2005; Zinn et al., 2004). These deficits do, however, improve with longer periods of abstinence (Mann, Gunther, Stetter, Ackermann, 1999); Rourke and Grant, 1999), indicating that impairment in executive functioning is partially reversible. Although speculations are tentative, the finding that impairment can improve with abstinence suggests that cognitive dysfunction may partly be a consequence of alcohol use rather than a premorbid vulnerability.

Neural findings. Given the pervasiveness of executive functioning deficits in alcoholics, a number of studies have sought to identify neural correlates of the observed impairment. Numerous studies have shown that executive functions are largely mediated by the frontal lobes (e.g., Casey, Giedd & Thomas, 2000; Shallice, 1988), specifically, the region of the prefrontal cortex (PFC; Lezak, 1995; Stuss & Benson, 1984). However, most neuroimaging and neurophysiological studies of the brains of alcohol-dependent individuals have focused on frontal lobe functioning more generally. Studies using positron emission tomography have identified decreased cerebral metabolic rates in the medial-frontal region of the frontal cortex in alcoholics (e.g., Adams et al., 1993; Gilman et al., 1990). Single photon emission computed tomography (Gansler et al., 2000; Nicolas et al., 1993), computerized tomography (Rosse, Riggs, Dietrich, Schwartz & Deutsch, 1997; Ron, Acker & Lishman, 1980), and magnetic resonance imaging (Pfefferbaum, Sullivan, Mathalon & Lim, 1997; Sullivan, Marsh, Mathalon, Lim & Pfefferbaum, 1996) studies have similarly provided evidence for diminished frontal lobe functioning. These results converge to document the presence of dysfunction and morphological abnormalities in the frontal lobes of chronic alcoholics (Moselhy, Georgiou & Kahn, 2001).

Taken together, the results of these studies suggest that alcoholism is associated with structural and functional changes in the brain, especially in the frontal lobes, that are associated with cognitive changes. However, most of these studies used clinically referred patients with long histories of alcohol dependence, leaving several important questions unanswered: 1) Does the observed cognitive impairment represent a change from pre-morbid functioning? 2) Is cognitive impairment a cause or a consequence of alcoholism? 3) If the observed deficits are in fact changes in functioning, at what point in the drinking history does this occur? Examining the neural and cognitive characteristics of younger, heavy drinkers without alcohol dependence, adolescents with a genetic risk for alcoholism, or both might provide at least partial answers to these questions.

Social Drinking

In light of the apparent cognitive consequences of alcoholic drinking, researchers have questioned whether similar impairments are observed among heavy “social” drinkers. Social drinkers are an important population to study because they use alcohol regularly but have not progressed to problematic alcohol use and, presumably, have had less exposure to its neurotoxic effects. Thus, careful study of social drinkers may reveal how much alcohol consumption is necessary to produce the cognitive deficits that are identified in persons with alcohol dependence.

Early studies conducted by Parker and Noble (1977, 1980) provided support for the *continuity hypothesis* (Ryback, 1971), which predicts a linear relationship between amount of alcohol consumed and cognitive deficits. However, a review of the literature on social drinking found that these results were not entirely replicable and questioned whether other *causal hypotheses* (i.e., alcohol-threshold) or *non-alcohol-causal hypotheses* (i.e., cognitive-causal, stress-emotional-causal, genetic-causal) may better account for the relationship (Parsons & Nixon, 1998; Parsons, 1986).

A substantial problem with the literature on social drinking is that studies have not consistently defined social drinking, with definitions varying from three U.S. standard drinks (USSD) per week (Carey & Maisto, 1987) to 105 USSD drinks per week (Williams & Skinner, 1990), making it especially difficult to make cross-study comparisons. To address this issue, in a review of 17 studies conducted between 1986 and 1996, Parsons and Nixon (1998) classified studies into two groups: those that found evidence of cognitive impairment and those that did not. Results showed that mean number of weekly drinks per week was significantly higher in the group with cognitive impairment, suggesting that impairment was only detectable in samples that drank most heavily and frequently. This review, which failed to provide support for non-alcohol causal hypotheses, instead suggested that cognitive impairment is related to the amount of alcohol consumed per occasion, but only after an individual's threshold for alcohol intake (MacVane, Butters, Montgomery & Farber, 1982) has been reached.

Parsons and Nixon (1998) concluded that consuming 5-6 USSD drinks daily over time increases risk for cognitive impairment, a risk that increases with daily consumption of 7-9 USSD drinks, and becomes most likely in persons with a daily consumption of 10 or more USSD drinks. These findings have implications for the current categorical classification of college student binge drinking (discussed below) and may make it difficult to detect cognitive impairment among heavy drinking college students.

College Students

Studies of college student drinking typically classify students according to whether or not they engage in *binge drinking* (Wechsler, Davenport, Dowdall, Moeykens & Castillo, 1994) which was defined by Wechsler and his colleagues as four or more drinks on a single occasion by women and five or more drinks by men (Wechsler, Dowdall, Davenport & Rimm, 1995; Wechsler & Nelson, 2001); students are further categorized by *frequent binge drinking* status, defined as binge drinking three or more times during a two-week period (Wechsler et al., 1994). Such categorization, which greatly reduces the variability in quantity and frequency of individual drinkers, may not be the best method for studying the effects of drinking. Consequently, several studies have instead classified college students based on the presence of an alcohol use disorder, as determined by the *Diagnostic and Statistical Manual of Mental Disorders, 4th Ed.* (DSM-IV; APA, 1994).

Studies that have elected to examine the heaviest and most problematic college-aged drinkers identify impairment on several neuropsychological measures. However, in many cases, there are few differences between drinkers and non-drinkers. For example, a cross-sectional study of first-year undergraduates revealed that students with alcohol use disorders (AUDs: alcohol abuse and alcohol dependence) performed more poorly on measures of visuospatial ability and motor speed, but did not differ from non-AUD students on measures of verbal ability, memory, or attention (Sher, Martin, Wood & Rutledge, 1997). These findings were especially pronounced for students who met criteria for alcohol dependence (versus abuse) and are generally compatible with those obtained in adults with alcohol dependence. However, at seven-year follow-up, there were relatively few differences in cognitive functioning between these groups, even though the students who had AUDs in the first year of college reported greater alcohol consumption at follow-up than those without AUDs (Wood, Sher & Bartholow, 2002). Based on the apparent lack of differences between groups, the authors concluded that heavy drinking during the college years does not seem to be associated with lasting impairments in cognition.

Studies that have specifically examined executive functioning as it relates to college student drinking generally have not reported a significant association between these variables (e.g., Wood et al., 2002; Blume, Marlatt & Schmaling, 2000; Sher et al., 1997). For example, the authors of a recent study aimed to determine whether the negative consequences of alcohol use could be explained by deficits in executive control (Whitney, Hinson & Jameson, 2006). The authors did not find a relationship between a general deficit in executive functioning and negative consequences of drinking, suggesting poor external validity of broad-spectrum measures of executive functioning. However, these findings contrast with those of an earlier study (Giancola, Zeichner, Yarnell & Dickson, 1996), which found a significant association between executive functioning and the severity of consequences of alcohol use. These conflicting results may be an artifact of methodological differences such as the inclusion of only male participants in a study (Giancola et al., 1996).

In contrast to the robust findings of executive functioning in alcohol dependent adults, studies of college student drinkers have largely failed to document similar impairment. Even when such deficits are noted, heavy drinking college students do not show impairment at the level observed in alcohol-dependent adults (Giancola & Tarter, 1999). Although causal conclusions cannot be drawn from cross-sectional studies, these results appear to suggest that a) cognitive impairments, including executive dysfunction, are only associated with heavy alcohol use that escalates beyond that which characterizes college student drinking, or b) it is necessary to look for moderating variables to detect cognitive impairment in college students.

Adolescents

Studies of alcohol-dependent adults and heavy social drinkers have provided evidence for the cognitive and neural changes that accompany protracted alcohol use.

However, it remains unclear when in a person's "drinking career" structural, functional, and/or cognitive changes occur (Tapert, Caldwell & Burke, 2004). The period of adolescence, commonly defined as the second decade of life (Monti et al., 2005), provides a unique window of opportunity to study the effects of alcohol on the brain, given that adolescents, developmentally, are old enough for risk factors to be detected but young enough that differences in potential risk markers cannot be attributed to the consequences of alcohol use (Nigg et al. 2004). Although many advances have been made in this arena, it remains unclear whether adolescent alcohol use definitively *causes* brain damage (Moss, 2008). This issue has proven sufficiently important that NIAAA released a Request for (Grant) Applications in January, 2007, specifically to address the consequences of alcohol use on the developing brain and whether potential deficits persist or recover. A review of the extant literature provides evidence for both pre-existing cognitive vulnerabilities toward alcohol use and cognitive consequences of alcohol use.

Neural development. Before considering neural and cognitive functioning in high risk or alcohol abusing adolescents, it is first necessary to consider the changes that occur in healthy adolescents during this period of development. Two main maturational events occur in the brain during this time: axonal myelination tissue and synaptic pruning (Blakemore & Choudhury, 2006). Myelination of axons serves to increase the speed of neural transmission and is completed in most brain regions during early childhood; however, myelination in the frontal cortex increases in the prefrontal area during adolescence (Clark, Thatcher & Tapert, 2008; Ashtari et al. 2007; Barnea-Goraly et al., 2005; Lenroot & Giedd, 2006) and continues into early adulthood (Moss, 2008;

Schneider et al, 2004). In contrast, the proliferation of synapse formation during the postnatal period results in an overabundance of connections that reaches peak volume around 12 years of age; these are then eliminated, or “pruned”. Pruning begins relatively late in the prefrontal cortex (Gotgay et al., 2004; Lenroot & Giedd, 2006; Sowell, Thompson, Leonard, Welcome, Kan & Toga, 2004) and continues through young adulthood (Moss, 2008; Sowell, et al., 1999; Giedd, et al., 1999). To summarize, the teen years and early-mid twenties are characterized by linear increases in myelination in the prefrontal cortex and decreases in prefrontal gray matter. Because the prefrontal cortex is one of the last brain regions to mature (Nigg et al., 2004; Casey, Giedd & Thomas, 2000; Giedd et al., 1999), it may be more sensitive to the effects of alcohol.

An imaging study of adolescents with alcohol use disorders showed that adolescents with alcohol use disorders have less prefrontal white matter volume than healthy controls (De Bellis, Narasimhan, Thatcher, Keshavan, Soloff & Clark, 2005). This is a potentially important finding, given that increasing white matter organization is associated with development of executive functioning in adolescents (Clark et al., 2008). Although this study did not determine whether delayed white matter organization was a result of alcohol use or predated it (Clark et al., 2008), evidence from experimental studies using animal models suggests that several areas of the juvenile brain, including the ventral prefrontal cortex, are more sensitive to alcohol-induced brain damage than are adult brains (Crews et al., 2000). Thus, it is possible that the adolescent brain is preferentially susceptible to alcohol induced neural changes. Unfortunately, all of the current evidence supporting the view that AUDs in human adolescents are associated with differences in brain structure and function come from small, cross-sectional studies that preclude causal conclusions.

High-risk studies. To address the question of causality, several lines of research have employed the *high risk paradigm*, which questions whether children of alcoholic parents exhibit cognitive impairments prior to the onset of problem drinking (Nigg et al., 2004). Having a biological parent with alcoholism is the strongest predictor of alcoholism in children (Schuckit, 1986). Therefore, if cognitive deficits exist in children with a family history of alcoholism, they may represent potential risk factors for the development of subsequent substance use disorders (Giancola & Tarter, 1999).

Studies reliably identify a relationship between family history of alcoholism and poorer cognitive functioning. Adolescent boys with a family history of alcoholism have poorer language skills (Tapert & Brown, 2000), lower full scale IQ, and weaker capacity for delay of gratification (Nigg et al., 2004). Children from *high-density* alcoholism families, defined by the presence of an alcoholic father and at least two other first or second degree alcoholic relatives, showed additional impairments on measures of visuocontructional abilities, working memory, and executive functioning at baseline assessment. When they were assessed three years later, between the ages of 11 and 17 years old, there were no group differences on visuoconstructional abilities or working memory; however, adolescents from high density alcoholism families remained impaired on measures of executive functioning (Corral, Rodriguez, Holguin & Cadaveira, 2003). These findings suggest that the development of executive functioning is affected by family history of alcoholism and that executive functioning does not “catch up” as readily as other cognitive abilities.

Other studies that specifically examined executive functioning have generally shown that at-risk adolescents are impaired in this domain (Nigg et al., 2004; Shoal & Giancola, 2001; Giancola & Tarter, 1999; Harden & Pihl, 1995). Such deficits are significantly related to the negative consequences associated with substance use (Shoal & Giancola, 2001) and age of first drink (McGue et al., 2001). Although some studies failed to demonstrate clear impairment (e.g., Nixon & Tivis, 1997), that may have been due to the variability of the measures used to examine executive functioning in cross-study comparisons. Executive functioning is a multi-faceted construct (Miyake, Friedman, Emerson, Witzki & Howerter., 2000) that cannot be readily captured by one common factor (Nigg et al., 2004); failure to provide a comprehensive battery of tests (e.g., Wisconsin Card Sorting Task, Trail Making Test) could result in conflicting findings.

Evidence from imaging studies corroborates the results of neuropsychological testing. Youth with a family history of alcoholism were shown to have less neural activation in prefrontal, occipital, and parietal regions during a behavioral inhibition task of executive functioning (Schweinsburg et al. 2004). In a recent study, high risk adolescents demonstrated less frontal activation during an anti-saccade measure of executive functioning (McNamee et al., 2008), confirming the presence of neural deficits in brain regions associated with inhibition among high-risk youth.

High-risk studies of adolescents sometimes include teens that currently use substances and/or have a substance use disorder. Inclusion of this group makes it more difficult to detect cognitive risk factors but does allow for the study of the synergistic effects of vulnerability and protracted use of alcohol and drugs. Substance-using adolescents with a family history of alcohol abuse show impaired attention (Tapert &

Brown, 2000) and executive functioning (Tarter et al., 2003). Executive dysfunction in this group is associated with more negative consequences of substance use (Shoal & Giancola, 2001) and appears to mediate the relationship between parental substance use disorder and the child's substance use disorder (Tarter et al., 2003).

Consequences of use. Attention has recently turned toward investigating the neuropsychological correlates of adolescent alcohol dependence, irrespective of whether or not there is familial risk for alcoholism. These studies have shown that alcohol dependence in adolescents is associated with impaired performance on measures of verbal abilities, processing speed (Brown, Tapert, Granholm & Delis, 2000), general executive functioning (Giancola & Tarter, 1999), and attention (Tapert, Granolm, Leedy & Brown, 2002; Tapert & Brown, 1999). Of note, attentional difficulties were most pronounced in adolescents who continued to abuse substances between baseline assessment and reassessment four (Tapert & Brown, 1999) and eight years later (Tapert et al., 2002). This finding suggests that a longer duration of alcohol use is associated with greater cognitive impairment in this domain.

In a recent review, Tapert, Caldwell and Burke (2004) concluded that several factors moderate the relationship between adolescent alcohol dependence and cognitive impairment in attention and visuospatial abilities. These include the severity of alcohol dependence as approximated by the number of withdrawal symptoms (Tapert et al., 2002; Brown et al., 2000; Tapert & Brown, 1999), family history of alcoholism (e.g., Tapert & Brown, 2000), and being female (Medina et al., 2008; Tapert et al., 2001; Moss et al., 1994). Further research is needed to explore the effect of these moderating variables on other domains of cognitive functioning.

Summary

In contrast to the cognitive impairment observed in persons with alcohol dependence, there is little evidence for similar impairment in heavy drinking college students. Several studies documented deficits in attentional abilities but did not detect deficits in other cognitive or executive functions. However, studies of alcohol-abusing adolescents and adolescents with familial alcoholism revealed impairment across the cognitive domains of verbal abilities, processing speed, attention, and general executive functioning. Social drinkers experience cognitive consequences of drinking, an effect that increases with amount of alcohol consumed. These studies provide evidence for cognitive risk factors that increase both the propensity for alcohol use and an association between protracted alcohol use and cognitive impairment. The contribution of premorbid impairment to the observed cognitive deficits in heavy drinkers is not yet entirely clear, although there is probably a synergism between the neurotoxic effects of alcohol and premorbid vulnerabilities (Garavan & Stout, 2005).

The fact that some persons continue to abuse alcohol despite increasing negative consequences raises the question of whether impairment in decision making best characterizes the apparent inability to learn from mistakes. Evidence for the relationship between impaired decision making and abusive drinking will be presented following a brief review of the literature on decision making.

Decision Making

Decisions under Uncertainty

Normal human decision making is characterized by the ability to choose between competing courses of action based on their expected outcomes (Balleine, 2007). Knowing the difference between or among options likely to produce favorable outcomes and those that are unlikely to do so is the hallmark of effective decision making and hence essential for successful navigation through life (Byrnes, 2002). This complex process, which requires the integration of multiple cognitive functions including attention, working memory, and response inhibition (e.g., Bechara, Damasio & Damasio, 2000; Balleine, 2007; Jameson, Hinson & Whitney, 2004), is recognized as a "higher level" executive function (Miyake, Friedman, Emerson, Witzki & Howerter, 2000). The cognitive demands of decision making are substantially reduced if the expected outcome of a decision is known and absolutely certain to occur; not surprisingly, the existence of such well-defined outcomes rarely characterizes real-world scenarios.

Instead, we are frequently faced with the challenge of choosing among several options whose consequences and the probabilities associated with each alternative are not fully known; these are known as *decisions under uncertainty*. For some decisions, both the outcome of a choice and the likelihood of its occurrence are known, but the probability of the outcome is not equal to 100%. When the outcome of a choice is not a sure thing, a decision is said to be risky; choosing among one or more risky options is aptly called *decision making under risk* (Yates, 1990; Bechara & Damasio, 2005). Alternatively, decisions made without any knowledge of outcome probabilities or of specific negative consequences are called *decisions under ambiguity* (Knight, 1921); in such a scenario, the decision maker knows there will some unspecified consequence of a given action, but does not know exactly what it will entail or how likely it is to occur.

There is good evidence that people respond differently to decisions under risk and ambiguity. For example, it is clear that people strongly dislike ambiguity and prefer options about which they are well-informed (Frisch and Baron, 1988). FMRI studies have shown that risk and ambiguity have separate neural correlates and are not simply points along a continuum of decisions under uncertainty (Hsu, Bhatt, Adolphs, Tranel & Camerer, 2005; Huettel, Stowe, Gordon, Warner & Platt, 2006). However, the process by which people actively decide among risky and ambiguous alternatives has been the subject of scholarly debate since the late 1700s.

Decisions under risk and ambiguity. Early theorists proposed that humans use formal judgment procedures in decision making. Drawing on rational Bayesian maximization of expected utility (Bayes, 1763/1958), these propositions operate on the assumption that humans are equipped with the knowledge and ability to utilize statistical probabilities to reach accurate decisions. For example, *Expected Value Theory* predicts that decisions are reached by multiplying the objective value of an option by the probability of attaining that outcome; a rational decision maker is expected to choose the option that has the best expected value (EV). One limitation of such theories is that they only apply in situations where the potential outcomes of the options have objective values that can be captured by a number and a probability that is associated with each of those outcomes. Daniel Bernoulli (1738/1954) extended Expected Value Theory, proposing that people incorporate subjective values, based on personal preferences and "wants," into calculations to aid in choosing among alternatives. His *Expected Utility Theory* predicts that people calculate an expected utility (EU) by multiplying the probability of an outcome by its subjective value.

Although it is unlikely that humans possess the knowledge (or the ability) to make these calculations, formal judgment theories nonetheless hypothesize that people would behave in accordance with these rational principles, and decide *as if* they had conducted a computational analysis (Yates, 1990). However, this is not what is observed in human decision making: people frequently demonstrate irrational decision making as shown by the fact that their probability judgments often deviate substantially from expected value and expected utility theories' predictions. Despite the limitations of Expected Utility Theory, it led to a very important prediction with regard to how people respond to decisions under risk: people tend to be *risk averse*, meaning that they are apt to choose a sure thing over a risky option, even when the options have equal EU. To illustrate, imagine a scenario in which you are invited to participate in a simple betting game with two options. If you choose the first option you have an 80% chance of winning $500.00 and a 20% chance of winning no money; if you choose the second option there is a 100% likelihood of being awarded $400. Which would you choose? Even though both options have the same EU (option 1 EU = ($500 x .80) + $0.00 x .20) and option 2 EU = ($400 x 1.00)), Expected Utility Theory predicts that you would choose the second option. However, it has since been shown that people are not *always* risk averse.

Kahneman and Tversky (1979) argued that Expected Utility Theory's assumption that utility assigned to an outcome (such as wealth) does not vary depending on the decision maker's current circumstances is flawed because it is *reference independent*. Based on cognitive perception research, Kahneman (2003, p. 704) noted that "the effective stimulus is not the new levels of stipulation but the difference between it and the existing adaptation level. The analogy to perception suggests that the carriers of utility (subjective preferences) are likely to be gains and losses rather than states of wealth…."

With regard to money, for example, people are not just sensitive to final amounts, but instead focus on the amount that is *gained* or *lost* in the process. It is important to recognize that a scenario in which a certain amount of money was expected to be gained while the actual amount obtained fell short of that goal might also be construed as a loss, even though there was a net financial gain. According to Kahneman and Tversky (1979), this interpretation will bias preferences in decision making.

To incorporate the effects of reference points on decision making, Kahneman and Tversky (1979) developed *Prospect Theory*, which proposes that the subjective value ascribed to an outcome is partly determined by whether it is a potential gain or a potential loss. This information is then combined with the relative uncertainty of the outcome and an overall decision-weight is calculated for each option so that the prospect with the highest value can easily be selected. One defining characteristic of Prospect Theory is that the value function is inverse for gains and losses such that persons are generally risk seeking in the domain of losses and risk averse for potential gains. It seems that, in order to protect status quo (based on a reference point), a person will likely choose a risky option where there is a certain probability that they will lose a set amount (or nothing) rather than choose an option where they are guaranteed to lose a specified amount.

The role of emotions. A shortcoming of older theories of decision making, such as those reviewed above, is their assumption that the process is based on so-called "cold" cognitive processes that are relatively devoid of emotional input. Newer theories have begun to recognize the importance of emotions (e.g., Huettel et al., 2006; Loewenstein, Weber, Hsee & Welch, 2000). Antonio Damasio (1994) was among the first to propose a theory, heavily grounded in neuroscience, that ascribes an important role to emotions in biasing the complex process of social and emotional decision making. This theory, known as the *somatic marker hypothesis*, suggests that *before* cognitively mediated decision making occurs, people think about the outcome of a choice and experience an emotional reaction, or a *somatic marker*. If the bodily and emotional states are processed at the cortical level, a person may consciously experience a "gut feeling" that directs attention toward or away from a given option. Alternatively, the somatic markers may be processed at the subcortical level without conscious awareness, but still serve to inhibit regulatory neural circuits that mediate appetitive or approach behavior (Damasio, 1994). Unconscious processing would likely result in choosing an advantageous option without an explicit preference for that choice or aversion to the alternative (Naqvi, Shiv & Bechara, 2006).

Somatic markers are thought to aid decision making in several important ways. First, they increase efficiency. Attention is immediately turned toward the negative consequences of a given choice and, depending on the strength of that signal, can lead to the automatic deletion of that option from further consideration (Damasio, 1994). Second, once somatic states are elicited, an overall positive or negative sum of the states will be formed. Whether perceived consciously or unconsciously, this net somatic state serves to bias the individual toward or away from an option (Bechara, 2003; Bechara, Tranel & Damasio, 2000). Finally, in cases where complex decision making is called for, somatic markers will have served to reduce the number of alternatives, thereby allowing for more efficient utilization of probabilistic strategies (Damasio, 1994).

The somatic marker hypothesis is consistent with propositions that outcomes tagged with these "hot" emotions will be most accessible and will have a greater role in biasing our choices (Stanovich and West, 2000). To that end, Kahneman (2003) recently used emotional biasing to explain Prospect Theory's central tenet that people are more sensitive to changes in wealth (i.e, gains or losses) than to absolute amount. He postulated that changes are more likely to evoke an emotional response, which in turn biases the subjective value of a potential gain or loss. The preference for risk taking in the domain of losses and for risk aversion toward gains can also be understood within the context of emotions. It may be that the fear associated with loss biases the decision maker toward the risky option, which necessarily presents a chance of losing a lesser amount than the sure option.

If potential threats or rewards are not present in the immediate environment, how are somatic markers generated? The hypothesis posits that somatic markers can be elicited via direct exposure or through conditioned responding. *Primary inducers* are automatic emotional responses that are generated on encountering a given stimulus whereas *secondary inducers* are generated when *thinking* about the rewarding/punishing properties of a stimulus (Damasio, 1994). Primary inducers typically precede the development of the conditioned response associated with secondary inducers; once a somatic state has been triggered by a primary inducer and experienced at least once, the somatic state will be stored for future recall via secondary emotional responding (Bechara & Damasio, 2005). Because humans have the ability to like or dislike things without ever having any direct experience with them, Damasio hypothesizes that secondary inducers can also be acquired through vicarious learning and knowledge of social norms. Whether obtained through direct or indirect experience, everyday decision making most commonly calls upon secondary inducers, since we are frequently required to imagine the anticipated outcomes of a choice.

Summary

Effective decision making requires an individual to set a goal, assign value to outcome options, and select the highest ranked alternative (Byrnes, 2002). Traditional theories of decision making assumed that humans incorporate probabilities and values in order to choose rationally among alternatives. Research and conventional wisdom has since shown that people's choices are rarely consistent with statistical prediction. Recently proposed theories ascribe an important role to emotions in biasing decision making, while still allowing for the possibility that people incorporate probabilistic calculations into the final decision. The somatic marker hypothesis has received much attention in the fields of decision making and neuroscience, and influenced the development of the Iowa Gambling Task, which is a primary measure of decision making in the present study.

Impaired Decision Making

Clinical observation confirms that persons with damage in a region of the frontal lobe known as the ventromedial prefrontal cortex (VMPC) repeatedly make faulty decisions and engage in behaviors that have negative consequences (e.g., Rahman, Sahakia, Cardinal, Rogers & Robbins, 2001; Tranel, 2002) in spite of otherwise intact cognitive functioning (e.g., Bechara, 2003; Bechara, Damasio, Damasio & Anderson, 1994). Indeed, the catalyst for the somatic marker hypothesis was Damasio's patient, Elliot (Damasio, 1994). A brief review of this case history will be useful in exemplifying the kinds of deficits experienced by VMPC patients.

Elliot was described as a good husband, a successful businessman, and a role model for his children until he developed a fast growing meningioma in his frontal lobe that required surgical resection. The surgery was successful in removing the tumor but it also resulted in damage to his right VMPC, the consequences of which were previously unknown. Shortly after surgery, Elliot began to show personality changes that shocked family and friends. Within three years he held a myriad of unskilled jobs, lost all of his savings to bankruptcy following a bad business venture, was divorced three times, and eventually had to live in the care of a sibling. The most fascinating aspect of Elliot's behavior was that, despite his serious deficits in decision making, he performed above average on all standardized neuropsychological tests. Specifically, his assessment revealed superior intellect, verbal and visual memory, language skills, visuospatial perception, and executive functioning. In short, standardized testing failed to document *any* impairment, which was both perplexing and frustrating.

After taking some time away from the case, Damasio recognized that, during all of their interactions, Elliot had never demonstrated the emotional reactions of a person who had experienced so many social and personal failures. Elliot's blunted emotions were not restricted to negative consequences: he seemed unable to generate any kind of emotional response, whether happiness, sadness, or frustration. This realization was the basis for Damasio's hypothesis that intact emotional functioning is requisite for effective decision making.

Assessing Decision Making Under Ambiguity with the IGT

Although clinical experience suggested a clear relationship between VMPC lesions and impaired real-world decision making in Damasio's patient, no valid laboratory analogue with which to assess this association empirically had yet been developed. Accordingly, Bechara, Damasio, Damasio, and Anderson (1994) developed the Iowa Gambling Task (IGT), which was designed to simulate real-world decision making under ambiguity (i.e., unknown probabilities and outcomes). Briefly, the IGT presents participants with four decks of cards from which they are told to make a long series of choice selections (100 trials), with the goal of maximizing hypothetical monetary earnings. Each card selection is associated with winning and losing a certain amount of money; two decks are advantageous in that they are associated with smaller immediate gains but smaller ultimate losses, whereas the other two decks have a larger immediate monetary gain but a greater monetary loss, ultimately resulting in a negative balance. Effective decision making on the IGT is characterized by the ability to estimate which decks are advantageous and which are disadvantageous in the long run, and then to select cards that will ultimately result in a net gain.

To establish its validity, Bechara et al. (1994) administered the IGT to patients with damage to the VMPC (N = 6), brain-damaged controls (N = 9), and healthy controls (N = 44). The three groups of participants initially sampled cards from all four decks but, after a few trials, the healthy and brain-damaged controls began to select more cards from the good decks (i.e., those associated with smaller immediate gains and losses). In contrast, VMPC patients appeared oblivious to deck contingencies and continued to choose more cards from bad decks, resulting in an ultimate net loss of money. Card selection effectively discriminated among groups and was consistent with clinical observations of the bad choices that VMPC patients make in everyday life. These results have been replicated in numerous subsequent studies and have established the IGT as a valid analogue of real-world decision making (e.g., Bechara, Damasio, Tranel & Damasio, 1997; Bechara, Tranel & Damasio, 2000; Bechara, Tranel, Damasio & Damasio, 1996; Clark & Manes, 2004; Tranel, Bechara & Denburg, 2002).

One question of interest is whether the failure to make advantageous choices on the IGT is due to insensitivity to future consequences (positive or negative), insensitivity to punishment, or hypersensitivity to reward. This question has been addressed in two ways. First, a variant of the IGT was developed in which deck contingencies were reversed: advantageous decks yield immediate losses but even higher future rewards and disadvantageous decks offer lower immediate punishments but even lower long-term rewards (Bechara et al. 1994). Because punishment is immediate and reward is delayed, a failure to switch to advantageous decks would indicate an aversion to punishment, while a preference for decks with high delayed reward would suggest hypersensitivity to reward. Studies using the variant of the IGT revealed that VMPC patients make more choices from disadvantageous decks, indicating that they are most influenced by immediate punishment and are comparatively insensitive to delayed reward. These findings suggest that insensitivity to punishment and hypersensitivity to reward do not best characterize VMPC patients' decision making deficits (Bechara et al., 2000; Bechara et al., 1994).

The second way this question was addressed was by measuring skin conductance responses (SCRs) after participants received reward or punishment in the original and variant versions of the IGT (Bechara et al., 2000). Evidence for hypersensitivity to reward includes a preference for decks with high delayed reward (advantageous decks in the variant version) and amplified SCRs following reward. Making more selections from decks with high immediate punishment (advantageous desks in the variant task), coupled with lower than normal SCRs in response to punishment, indicates insensitivity to punishment. Finally, indices of insensitivity to future consequences include a preference for decks with low immediate punishment and normal SCRs after receiving punishment or reward. Results from this study converge with those of Bechara et al. (1994) and provide physiological evidence that persons with VMPC lesions are insensitive to future consequences (Bechara et al., 2000), commonly referred to as ‘myopia for the future.’

Skin conductance responses reflect autonomic arousal, so they are in fact a somatic marker (Rahman et al., 2001). They have been useful in determining whether the somatic marker hypothesis can account for decision making deficits among persons with damage to the VMPC. Bechara et al. (1996) measured the SCRs of healthy controls and VMPC patients in response to reward and punishment on the IGT. Both groups generated SCRs in response both to reward and punishment, which is evidence for the normal development of primary inducers; however, controls also generated SCRs prior to selection from bad decks whereas patients did not. To determine whether successful decision making is governed by covert processing of somatic markers, Bechara et al. (1997) measured SCRs before card selection and periodically asked participants to explain what they knew about how the game worked. They found that the IGT can be described by three phases: pre-hunch, hunch, and conceptual. By card 20, healthy participants generated anticipatory SCRs to bad decks even though they could not verbalize which decks were bad (pre-hunch phase). However, by card 50 they were able to verbalize a hunch toward bad decks that corresponded to anticipatory SCRs, and by trial 80 many expressed conceptual knowledge about good and bad decks. In contrast, none of the VMPC patients generated anticipatory SCRs or made advantageous choices; of the few VMPC patients that reached the conceptual level, *none* made advantageous choices.

Taken together, these findings suggest that VMPC patients do not generate somatic markers when thinking about future consequences (i.e., secondary inducers) even though they have intact primary inducers. The VMPC patients' poor performance on the IGT, coupled with their lack of anticipatory SCRs, suggests that somatic signaling is necessary for effective decision making. Results from these studies also indicate that somatic signaling does not need to be consciously perceived to influence decision making. Finally, there is evidence that even when VMPC patients can identify the best option, they do not necessarily choose in accordance with that knowledge (Bechara & Damasio, 2005).

Assessing Decision Making Under Risk with the Cups Task

The IGT is largely a measure of decision making in the face of ambiguity, but it has recently been suggested that later trials in the IGT represent decisions under risk for healthy participants because they have a sense of which decks are good and bad (Brand, Recknor, Grabenhorst & Bechara, 2007). Even if a convincing argument could be made that the IGT reflects both types of decisions under uncertainty, there is no way of knowing when decision making switches from ambiguous to risky. Another potential limitation of the IGT is that gains and losses are mixed, which precludes an exploration of whether decision making deficits differ as a function of domain. In an effort to add to the literature on decision neuroscience, Weller, Levin, Shiv, and Bechara (2007) used a modified version of the original Cups Task (Levin & Hart, 2003) to determine whether separate neural systems contribute to decision making for gains and losses.

The Cups Task is an analogue betting task in which participants must choose between a safe bet (100% probability of winning a quarter) versus a risky bet (a certain probability of winning *x* number of quarters or no quarters). The domain (gain versus loss), associated probabilities of winning or losing, and the expected value (EV) of the options are manipulated across trials. Consistent with the preference shift predicted by Prospect Theory, normal adults make more risky choices to avoid a loss than to achieve a gain (Levin, Hart, Weller & Harshman, 2007). The Cups Task has demonstrated stability in decision making over a three-year period in children and adults (Levin, 2007).

Weller et al. (2007) obtained a sample of patients with damage to the amygdala (N = 16) or the VMPC (N = 7) and a group of healthy controls (N = 30). Using a computerized version of the Cups Task, they found that VMPC patients made more risky choices for gains and losses and were also less sensitive to EV than either comparison group. Although patients with damage to the amygdala performed like controls when faced with potential losses, by making a similar number of risky choices and showing sensitivity to EV, they performed like VMPC patients in the domain of gains, by making many more risky, disadvantageous choices than controls. Consistent with studies of lesion patients using the IGT, Weller et al. (2007) reported that damage to the VMPC is associated with impaired decision making regardless of domain. A more recent study also implicated the insula as being involved in decision making for gains (Weller, Levin, Shiv & Bechara, 2009). Thus, adaptive decision making with respect to gains seems to be specifically modulated by several neural regions, which underscores the importance of considering separately decision making with respect to gains and to losses.

Summary

The IGT appears to be a valid analogue to real-world ambiguous decision making. It effectively captures the bad choices that patients with damage to the VMPC make in their daily lives. The Cups Task provides a laboratory measure of risky decision making and allows for examination of the neural substrates of gains versus losses. Numerous studies, including those using lesion, imaging, and psychophysiological methodology, confirm the importance of the VMPC in effective decision making. Although other neural regions, such as the amygdala, and insula, play roles in decision making, the VMPC appears to regulate these processes and influence the ultimate decision.

Substance Use and Decision Making

According to the *DSM-IV* (APA, 1994), compulsive drug use in the face of physiological, social, and personal substance-related negative consequences is an essential feature of substance dependence. This pattern of bad choices is similar in important ways to the behavior of patients with damage to the VMPC. Both groups make choices that are immediately reinforcing, show little regard for future consequences, and often deny or are unaware that they have a problem (Bechara, 2003; Rogers et al., 1999). Given the apparent similarities between substance dependent individuals and VMPC patients, attention has recently turned toward exploring the role of impaired decision making in compulsive substance use. The somatic marker hypothesis (Damasio, 1994) represents one possible pathway by which addictive behavior is initiated and maintained.

When applied to addictive behaviors, the somatic marker hypothesis predicts that compulsive drug use despite negative consequences is due to faulty decision making mechanisms. Before the patient obtains direct experience with substances, these negative consequences should be present due to societal norms, legal sanctions, and vicarious learning. If decision making mechanisms are compromised, these individuals may not be able to anticipate the negative consequences of their drug and alcohol use; this would clearly represent a risk factor for initiation of substance use. Alternatively, once substance use has begun and negative consequences have been experienced, somatic marker impairments might contribute to progression of substance use from social use to dependence as the person fails to learn from previous mistakes (Bechara, Dolan & Hindes, 2002; Noel et al., 2006).

Impaired somatic responding in persons with substance dependence has been hypothesized by Bechara and his colleagues (2002) to result from an imbalance between functioning in the orbitofrontal/VM-insular cortex and the amygdala-ventral striatum. This imbalance can lead to compulsive substance use in two ways. First, addicts may be overly sensitive to primary inducers for the natural rewarding properties of drugs and alcohol and readily generate a somatic marker when the substance is in the immediate environment, while being less responsive to secondary inducers for the associated negative consequences. Alternatively, addicts may generate a strong somatic marker from secondary inducers when thinking about the positive features of use and a weak somatic response from the primary inducer of immediate punishment. Both pathways suggest that addicts may have compromised amygdala and VMPC functioning, as evidenced by the inappropriate response to primary and secondary inducers.

Studies Using the IGT

To test the hypothesis that substance dependent individuals (SDI) have deficits in decision making comparable to those of VMPC patients, the IGT was administered to SDI, VMPC patients, and healthy controls (Bechara, Dolan, Denburg, Hindes, Anderson & Nathan, 2001). Consistent with expectations, SDI and VMPC patients chose significantly more cards from disadvantageous decks than did healthy controls. However, individual variation was such that not all SDI showed impaired performance and not all controls made advantageous choices. To further characterize this deficit, these authors calculated the proportion of SDI that fell within the range of performance by VMPC patients. This analysis revealed that 61% of SDI performed in the impaired range versus 32.5% of controls; however, 39% of SDI were unimpaired, indicating that while VMPC dysfunction is associated with addiction, it is not a feature of the behavior of all persons with substance dependence. These findings have been replicated across many different groups of substance users, including alcoholics (Noel, Bechara, Dana, Hanak & Verbanch, 2007; Mazas, Finn & Steinmetz, 2000; Bechara et al., 2002), college student marijuana abusers (Stout, Rock, Campbell, Busemeyer & Finn, 2005), and persons dependent on methamphetamines (Bechara & Martin, 2004; Gonzales, Bechara, & Martin, 2007), cocaine (Grant, Contoreggi & London, 2000), and opiates (Petry, Bickel, & Arnett, 1998).

Given the behavioral similarities between VMPC patients and SDI on the IGT, Bechara and Damasio (2002) sought to determine whether SDI showed similar impairment. As an index of somatic marker induction, SCRs were collected from SDI, VMPC patients, and healthy controls both before IGT card selection and immediately after punishment (Bechara & Damasio, 2002). Previous studies had established that although VMPC patients generate SCRs in response to punishment they do not develop anticipatory SCRs (Bechara et al., 1997) before choosing from bad decks. Bechara and Damasio (2002) similarly found that VMPC patients generate SCRs following punishment, an effect that was also observed in SDI and healthy controls. Although smaller in magnitude, SDI generated anticipatory SCRs before choosing from disadvantageous decks as did healthy controls, a response that was not observed among VMPC patients. A slightly different pattern emerged when SDI were dichotomized, based on whether IGT performance was within the impaired range of VMPC patients. These results showed that SDI who performed in the impaired range on the IGT failed to generate SCRs prior to selecting from disadvantageous decks, suggesting that some SDI are behaviorally and physiologically indistinguishable from normal controls while others have compromised decision making abilities characteristic of VMPC patients.

Bechara, Dolan, and Hindes (2002) administered the variant IGT and then assessed SCRs to determine whether hypersensitivity to reward or insensitivity to future consequences best characterizes the decision making deficits observed in some SDI. The authors assumed that hypersensitivity to reward would be demonstrated by impairment on the original IGT, normal performance on the variant version, and large SCRs both in response to, and in anticipation of, reward. In contrast, impaired performance on both the original and variant IGT, coupled with normal reward SCRs, but deficient anticipatory SCRs, were thought to signal insensitivity to future consequences (positive or negative). The results of this study provided evidence for three groups of SDI. The first group is indistinguishable from healthy controls: they perform advantageously on both the original and variant IGT and generate anticipatory and punishment SCRs. A second group of SDI displays behavioral and physiological similarities to VMPC patients, making more disadvantageous choices on the original and variant IGT, and failing to generate anticipatory SCRs. Finally, a third group appears to be hypersensitive to reward, as demonstrated by impairment on the original task (but not on the variant), abnormally high reward SCRs, and anticipatory SCRs prior to choosing from advantageous decks.

The small group of SDI indistinguishable from healthy controls on behavioral and physiological measures of decision making is perhaps the most perplexing. In an effort to understand their behavior, Bechara, Dolan, & Hindes (2002) suggest that although the choices these individuals make in real-life look like bad decisions, they may actually be the result of faulty learning over which they have little control. Thus, if a substance user grew up in an environment in which drug and alcohol use were socially sanctioned, and if he or she failed to experience any severe negative consequences of this use, then the experience would likely not be tagged with a negative somatic marker. In that case, failure to generate a somatic marker when thinking about using the substance would not be reflective of VMPC dysfunction but, instead, would be indicative of a history of reward without future punishment. Further, if the delayed punishment of substance use is not greater than the immediate reward, then choosing to use a substance does not necessarily reflect a deficit in decision making (Bechara, 2003). Drug and alcohol use that meets with few consequences may not be a problem, which underscores the importance of assessing negative consequences associated with substance use and, if possible, determining the extent to which they are associated with laboratory measures of decision making (Noel et al., 2006).

To test the hypothesis that the subgroup of SDI with normal performance on the IGT performance may not have experienced many negative consequences, Verdego-Garcia, Bechara, Recknor & Perez-Garcia (2006) administered the Addiction Severity Index (ASI: McLellan et al., 1992), which asks about consequences of substance use, to this group. Hierarchical regression analyses showed that medical, legal, and substance related problems on the ASI were predictive of impaired decision making, as reflected in IGT performance. In like fashion, Bechara et al. (2001) found that the ability to maintain gainful employment is a good predictor of performance on the IGT among SDI (Bechara et al., 2001), again supporting the relationship between objective markers of negative consequences and impaired decision making. These findings both provide additional evidence of the IGT's ecological validity and support the possibility that, although addicts with VMPC dysfunction may be unable to overcome their addiction no matter how great its negative consequences, addicts with normal VMPC functioning may have a better chance to do so —when the cost of continued use becomes too great (Bechara et al., 2002).

Discounting of Delayed Rewards

When presented with the choice of an immediate or delayed reward, many people prefer the option associated with immediate reinforcement. What may be less intuitive—and from an economic perspective, less advantageous—is that people will often choose a smaller immediate reward over a larger delayed reward. This phenomenon, known as *delay discounting,* is best described by a hyperbolic function where the discounting rate of delayed rewards is directly proportional to the delay interval (Ainslie, 1992). Studies of delay discounting commonly focus on the rate at which people discount; steeper discounting reflects greater impulsivity and less adaptive decision making (Bickel & Marsch, 2001).

It has been suggested that delay discounting may provide a useful way to describe the impulsive behavior and loss of control that characterize addiction (Bickel & Marsch, 2001). Indeed, many studies have confirmed that persons with cocaine dependence (Montessero et al, 2001), alcohol use disorders (Petry, 2001, 2007; Petry & Casarella, 1999), nicotine addiction (Baker et al., 2003), and polysubstance abuse (Petry, 2002) discount at a steeper rate than healthy controls. Greater discounting of delayed rewards can also be observed in persons with nonclinical levels of alcohol use (Field, Christiansen, Cole & Goudie, 2007; Kollins, 2003), and has been shown effectively to discriminate between heavy and light college student drinkers (Vuchinich & Simpson, 1998).

Although no studies have directly addressed whether steeper discounting is a risk factor for substance use or whether it is only a consequence of use (Vuchninich & Simpson, 1998), a recent study conducted by Dom, D'haene, Hulstijn and Sabbe (2006) employed a cross-sectional design to examine differences in rate of discounting between early onset alcoholics (EOAs) and late onset alcoholics (LOAs). Because EOA but not LOA is associated with the personality traits of impulsivity and sensation seeking, the authors hypothesized that EOAs would show greater impulsivity on the DDT, as demonstrated by steeper discounting of delayed rewards. The results of this study supported this hypothesis: the authors concluded that impulsive decision making may be specifically associated with early onset of substance use. They also interpreted the findings as evidence that impulsive decision making reflects a trait variable, and dismissed the likelihood that it is a consequence of drug or alcohol use.

Studies that have examined the relationship between measures of delay discounting and the IGT conclude that although the tasks are related, they make independent contributions to decision making (Dom, De Wilde, Bieke, Hulstijn & Sabbe, 2007; Montessero et al., 2001; Olson et al., 2007). Specifically, delay discounting appears more closely related to impulsivity (e.g., Madden, Petry, Badger & Bickel, 1997; Olson et al., 2007; Vuchinich & Simpson, 1998) than do IGT scores (Bechara, 2003), thus justifying the use of both measures more fully to approximate decision making abilities.

Summary

Behavioral and physiological findings from a number of studies using the IGT provide compelling evidence that a substantial proportion of SDI have decision making deficits similar to those of persons with lesions to the VMPC. Dysfunction of the VMPC likely contributes to poor decision making in at least some persons that abuse drugs or alcohol. Substance users also show compromised decision making in that they steeply discount rewards that are delayed. What remains in question is whether this impairment is best described as a risk factor or as a consequence of substance use. Although presently available studies do not allow a definitive conclusion to be reached, Bechara (2005) has hypothesized that decision making deficits likely presage addiction. This contention is based on the fact that addicts repeatedly choose to use substances in the face of increasing negative consequences well before their abuse causes damage to the brain. Thus, it may be that some individuals have relatively compromised decision making abilities that place them at greater risk for progression to addiction (Noel et al., 2006), which may then be exacerbated by continued substance use (Verdego-Garcia et al., 2006). The speculative hypothesis that impaired decision making is a risk factor for problematic substance use should be empirically investigated

College Student Drinking and Decision Making

Studies of Decision Making in Adolescents

Adolescence is often marked by poor decision making, as evidenced by risky behaviors such as reckless driving, unsafe sex, and experimentation with substances (Arnett, 1992). Standardized measures of decision making effectively capture this impairment: whereas healthy adults have IGT net scores over 20 (Bechara, Damasio & Damasio, 2000; Mazas, Finn & Steinmetz, 2000), healthy 14-17 year-olds have been shown to obtain average net scores as low as 13 (Hooper, Luciana, Conklin & Yarger, 2004). There is, however, clear evidence that decision making abilities improve during the teen years. Adolescents aged 14 and older make more advantageous selections on the IGT over time than do 9-13 year-olds (Hooper et al., 2004; Overman, Frassrand, Ansel, Trawalter, Bies & Redmond, 2004), and older adolescents discount rewards less steeply than younger adolescents (Olson, Hooper, Collins & Luciana, 2007).

Given adolescents' propensity to engage in risky behaviors, two research groups have investigated whether performance on the IGT is associated with substance use in high-school-aged adolescents. Contrary to expectations, Overman and colleagues (2004) found no relationship between overall performance on the IGT (i.e., net score) and use of alcohol, tobacco, or drugs. However, a different picture emerges when learning is considered across trials. A recent study of Chinese high school students examined whether learning to choose cards from advantageous decks differed between binge drinkers and non-binge drinkers. The results showed that, compared to students who never drank alcohol, students who reported binge drinking at least once in the past 30 days did not learn to choose advantageously across trials (Johnson et al. 2008). The discrepant results between these studies might be due to differences in statistical analysis, suggesting that collapsing data across trials, rather than measuring the ability to shift performance over time, may obscure important differences in decision making. Alternatively, cultural differences may account for the surprising results; it may be that experimentation with substances is more normative among American than Chinese adolescents, and not due to faulty decision making processes.

Irrespective of substance use, performance on decision making tasks continues to improve throughout the late teen years and early twenties. Adolescents aged 12-16 do not show learning over trials on the IGT to the same degree as young adults aged 18-25 (Crone, Vendel & van der Molen, 2003). From a developmental perspective, college students represent an appropriate population in which to study decision making, since they should have nearly or fully developed their decision making abilities.

Prevalence of Alcohol Use

Wechsler’s national survey of undergraduate drinking, the College Alcohol Study (CAS: Wechsler, Davenport, Dowdall, Moeykens & Castillo, 1994), affirmed the ubiquity of abusive drinking on many U.S. college campuses. Approximately 40 percent of American college students met criteria for binge drinking, and almost 20% of the students in the same survey met the criterion for frequent abusive drinking. Similar prevalence estimates have been obtained from the Core Institute, Monitoring the Future, the National College Health Risk Behavior Survey, and the National Household Survey on Drug Abuse (O'Malley & Johnston, 2002). Despite subsequent efforts to reduce binge drinking on college campuses, CAS findings have proven to be very stable over during the years since 1993 (Wechsler, Dowdall, Maenner, Gledhill-Hoyt & Lee, 1998; Wechsler, Lee, Kuo, & Lee, 2000).

College students who binge drink are more likely to report such frequent adverse consequences of drinking as missing class, spending less time studying, experiencing unplanned and/or unsafe sex, becoming injured, and getting into legal trouble (Wechsler et al., 1994; Perkins, 2002; Engs, Diebold & Hanson, 1996; Williams, Powell & Wechsler, 2003). Students who meet frequent binge drinking criteria report these negative consequences at nearly double the rate reported by non-frequent binge drinkers (Wechsler et al., 1994), which is of particular concern given that many students drink at levels that greatly exceed the criteria for binge drinking (White, Kraus & Swartzwelder, 2006). Students with alcohol use disorders during college are likely to complete fewer years of education and obtain less prestigious occupational employment at 10 year follow-up than their peers without such diagnoses (Jennison, 2004). This troubling finding applies to a large number of students: a study of more than 14,000 college students revealed that 31% and 6% endorsed symptoms consistent with diagnoses of alcohol abuse and dependence, respectively (Knight, Wechsler, Kuo, Seibring, Weitzman & Schuckit, 2002).

Whether classified by binge drinking status or alcohol use disorder diagnosis, college students experience many serious consequences of drinking, thereby providing compelling evidence that such behavior is an example of deficient decision making (Bechara, 2003). Like persons with substance dependence, many of these students are seemingly impervious to the negative consequences of their behavior, as evidenced by continued binge drinking (Wechsler, Lee, Nelson & Kuo, 2002). In light of the apparent poor decision making, it is surprising that so few studies have empirically examined this relationship in college students.

Studies of Decision Making in College Students

Only two studies have specifically considered the association between decision making and drinking among college students. Goudriaan, Grekin, and Sher (2007) used latent class growth curve modeling to characterize trajectories of binge drinking across the first two years of college. They reported four classes of drinkers: low-binge, moderate-binge, increasing-binge, and heavy-binge. This research group administered the IGT at the study's final time point to determine whether binge drinking class was associated with impaired decision making across trials. Consistent with expectations, chronic heavy-binge drinkers performed more poorly on the IGT than did low-binge drinkers. Heavy alcohol use at the first time point, but not at the subsequent four waves, was predictive of disadvantageous decision making, possibly suggesting that length of alcohol use contributed to the observed relationship. Because decision making was measured after data on drinking were collected, and was only measured at one time point, it cannot be ascertained for certain whether poor decision making represented a risk factor for drinking in this sample.

Another recent study (Figlock & Nathan, unpublished) sought to determine whether binge drinking college students show deficits on the IGT like those of alcohol dependent individuals, and whether performance on the Cups Task is associated with college student drinking. In contrast to the results found by Goudriaan and colleagues

(2007), binge drinking status in this sample was not associated with deficits in decision making as reflected by IGT scores. However, when gains and losses were considered separately by means of the Cups Task, frequent binge drinking among undergraduates in their senior year of college was found to be associated with less adaptive decision making. Although these results do not readily support the hypothesis that heavy drinking in college students is associated with general impairments in decision making, they do underscore the importance of separately considering decision making with respect to gains and losses.

Both of the studies that examined decision making and college student drinking have several important limitations. First, the Goudriaan group (2007) only analyzed trial blocks 1-4, so it is unclear how participants performed in the last 20 trials of the IGT. Although they found statistically significant differences between heavy and low binge drinkers, it is important to note that all drinking classes shifted to good decks over time and obtained very high net scores, which is not characteristic of studies of clinically referred populations (e.g., Bechara et al., 2001). Second, both studies categorically classified students according to binge drinking status; given the current debate over whether the Wechsler definition of binge drinking may be too low (White et al., 2006), it is possible that important variability was obscured. Statistical analyses that allow drinking to be measured continuously over time, such as growth curve analysis, will allow for examination of whether decision making differs among the heaviest and most extreme drinkers. Finally, both studies assessed decision making at only one time point, thereby providing little information on the temporal precedence of decision making or binge drinking. Longitudinal studies are needed to determine whether impaired decision making is a risk factor for binge drinking during college.

Risk Factors for College Student Drinking

The first year of college is a critical period during which many students who did not drink in high school transition to heavy and frequent alcohol use (Hartzler & Fromme, 2003). A national survey of college students documented that more than 25% of first year students who are current binge drinkers did not typically binge drink in high school (Weitzman, Nelson & Wechsler, 2003). Although drinking patterns fluctuate across the first year of college in response to holidays and final exams (Del Boca, Darkes, Greenbaum & Goldman, 2004; Greenbaum, Del Boca, Darkes, Wang & Goldman, 2005), Grekin and Sher (2006) determined that between 11-15% of students consistently meet criteria for alcohol dependence during this period. The first year of college also represents a critical period academically; a substantial portion of the total growth of subject-matter acquisition and critical thinking skills are acquired during this time (for a review, see Pascarella, 2005). Given the prevalence of drinking and its potential health and academic consequences, identifying risk factors for drinking during this time is warranted.

A recent review identified several variables that consistently emerge as risk factors for increased drinking during the first year of college (Borsari, Murphy & Barnett, 2007). Several of these risk factors also predict performance on measures of decision making and will be considered in the present study. Familial abuse of alcohol is the most robust predictor of increased alcohol use (Sher & Gotham, 1999; Petry, Kirby & Kranzler, 2002; Pullen, 1994), and also predicts a lower likelihood of transitioning out of heavy drinking following college (Jackson, Sher, Gotham & Wood, 2001). Although decision making and family history have not been specifically considered within the adolescent population, familial alcohol abuse is associated with poorer performance on measures of executive functioning among adolescents (e.g., Nigg et al., 2004; Shoal & Giancola, 2001).

Precollege alcohol use also predicts binge drinking in college (Wechsler, Dowdall, Davenport & Castillo, 1995) and is associated as well with becoming a regular drinker in college (Weitzman et al., 2003). College students with a longer history of alcohol use perform more poorly on the IGT (Goudriaan, et al., 2007), as do alcoholics with a greater number of years of drinking (Noel, Bechara, Dan, Hanak & Verbanck, 2007). While these findings do not prove that impaired decision making is a consequence of drinking, they do highlight the importance of examining the extent to which decision making and abusive drinking depend on length of drinking history.

The personality dimension described as "impulse expression/sensation seeking" is consistently associated with more alcohol use and related problems in college students (Baer, 2002; Brennan, Walfish & AuBuchon, 1986; Del Boca et al., 2004; White et al., 2006). It is also predictive of an alcohol dependence diagnosis in this group (Grekin & Sher, 2006). Latent growth curve analysis has demonstrated that sensation seeking increases over time, an increase that systematically covaries with increased alcohol use during a six-year period (Crawford, Pentz, Chou, Li & Dwyer, 2003). Research examining whether impulsivity is related to impaired decision making on the IGT is mixed. Some studies have found an association between self-report measures of impulsivity and disadvantageous decision making (Davis, Patte, Tweed & Curtis, 2007;

Suhr & Tsanadis, 2007; Zermatten, Van der Linden, d'Acremont, Jermann & Bechara, 2005) while others have not (Dom, De Wilde, Hulstijn & Sabbe, 2007; Franken & Muris, 2005; Monterosso et al., 2001).

Male college students consistently drink more alcohol than their female counterparts (O'Malley & Johnston, 2002; Wood, Read, Mitchell & Brand, 2004; Greenbaum et al., 2005). There are also gender differences with respect to decision making, but the direction of the relationship is less clear. For example, several studies have shown that men and women perform equally well on the IGT (Fein, Klein & Finn, 2006; Stout et al., 2005), whereas others have found that men make more advantageous choices (Bolla, Eldreth, Matochik & Cadet, 2001; Overman et al., 2004; Reavis & Overman, 2001) but that women choose more cards from decks with infrequent punishment (Goudriaan et al., 2007; Hooper et al., 2004). Carefully controlled studies in which gender is considered as a potential moderator may help to clarify the nature of the relationship.

Positive expectations for alcohol use are associated with higher levels of drinking at the beginning of the first year of college (Del Boca et al., 2004) and effectively distinguish between students who increase or maintain drinking levels over the first year of college (Greenbaum et al. 2005). Alcohol expectancies predict binge drinking and negative consequences (Biscaro, Broer & Taylor, 2004; Blume, Schmaling & Marlatt, 2003; Wood, Nagoshi & Dennis, 1992) and are associated with a diagnosis of alcohol dependence (Wood, Sher & Strathman, 1996). Alcohol expectancies may be associated with decision making to the extent that they reflect hypersensitivity to reward, which has been offered as an explanation for impaired decision making in some individuals with substance dependence (Bechara, Dolan & Hindes, 2002).

Summary and Hypotheses

Compared to healthy adults, adolescents make more risky choices and perform more poorly on laboratory measures of decision making abilities, such as the IGT. Although performance on the IGT typically improves until early adulthood, college students are a unique population of young adults who frequently engage in risky behaviors in everyday life. The heavy and frequent drinking that commonly characterizes the behavior of college students is met with a plethora of negative consequences, and is, as a result, suggestive of poor decision making. Whether college students display such impairment on laboratory measures of decision making has not been adequately addressed. The few studies that have been conducted yielded mixed findings, and none directly considered whether poor decision making is a risk factor for binge drinking during college.

The present study is guided by two primary aims. The first is to determine whether deficits in decision making temporally precede heavy and frequent drinking during the first year of college. It is expected that poorer decision making at the beginning of the first year of college will predict a steeper increase in drinking during the academic year, but that meeting criteria for binge drinking will not predict a change in decision making. The second aim is to examine how decision making interacts with other established risk factors for college student drinking. It is expected that poorer decision making at the initial measurement period (Time 1) will be more strongly associated with escalation in alcohol use if participants are male, have a family history of alcohol abuse, report a longer history of pre-college alcohol use, hold more positive alcohol expectancies, and are more impulsive.

Studying the relationship between impaired decision making and drinking among college students assumes that drinking has been met with negative consequences; accordingly, a third aim of the present study is to describe the extent to which drinking and negative consequences covary over the first year of college. A fourth, and related, aim is to determine whether measures of decision making have ecological validity in a sample of college student drinkers, as has been demonstrated in adults with substance dependence. Ecological validity is the extent to which "associations are found between test scores and behaviors that occur external to the psychological evaluation in the real world" (Ready, Stierman & Paulsen, 2001, p. 314). Thus, I expect negative consequences of drinking to be associated with performance on measures of decision making abilities. Finally, an exploratory analysis will be conducted to assess the stability of decision making during the first year of college. To the best of the author's knowledge, no empirical studies have questioned whether decision making abilities vary during this critical period of academic and social development.

CHAPTER II

METHOD

Participants

First-year students (*N* = 138) at the University of Iowa were recruited from the Elementary Psychology subject pool in September, the first full month of the fall semester. Students were eligible to participate in the study if they were first-year students and at least 18 years of age. Data from two participants were excluded because of a computer malfunction that resulted in incomplete data for two measures of decision making. Consequently, the final sample consisted of 136 participants.

Procedure

Participants interested in enrolling in the study signed up using the web-based system maintained by the course coordinator for Elementary Psychology. The study description in the research exposure sign-up system clearly conveyed the expectation that participants would return for additional testing sessions at the end of the fall (November/December) and spring semesters (April/May). Power analyses indicated that a sample size of 85 participants was needed at Time 3; due to anticipated attrition, it was necessary to oversample at baseline.

Informed consent was obtained during the first testing session. Although students had the option to decline to participate in future testing sessions, students who consented to participate were automatically signed up for a follow-up session in late-November/early-December; during the first testing session, participants were asked to provide contact information to schedule a final assessment in mid-April/early-May. Because undergraduate drinking quantity and frequency have been shown to decrease during the week of final examinations (Greenbaum et al., 2005), follow-up assessments were not scheduled during the two weeks prior to the close of each semester.

This study utilized both self-report questionnaires and laboratory measures of decision making. Students who consented to participate completed questionnaires assessing sociodemographic and drinking variables, expectations of the effects of alcohol use, and impulsivity personality traits at the three time points. At each assessment point, participants also completed three validated laboratory measures of decision making.[1] Participation took approximately one hour at each session. For participation at Times 1 and 2, students received credit toward their research participation requirement for Elementary Psychology. Participants could not receive research credit at the study's final time point in April/May because they were no longer enrolled in Elementary Psychology. Instead, they received monetary compensation for their time, and were offered a gift card in the amount of $15.00 for their participation.

Self-Report Measures

Drinking Behavior

Participants provided information on current and past drinking behavior, including quantity and frequency of binge drinking and eleven associated negative consequences. Items were adapted from the questionnaire administered in the College Alcohol Study (Wechsler et al., 1994). Family history of alcohol problems was also assessed. For analyses using negative consequences, a composite was computed by aggregating the total number of items endorsed by participants.

Alcohol Use Disorders Identification Test

The Alcohol Use Disorders Identification Test *(AUDIT; Saunders, Aasland, Bobor, de la Fuente & Grant*, *1993)* is a 10-item self-report questionnaire used to help screen for symptoms of harmful drinking and substance dependence, as specified in the ICD-10 (World Health Organization, 1993). Items were chosen on the basis of correlations with daily alcohol intake, regular consumption of six or more drinks per occasion, and discriminability between healthy controls and persons with alcohol problems. Sample items include “How often during the last year have you failed to do what was normally expected from you because of drinking?” and “Have you or someone else been injured as a result of your drinking?” Scores range from 0-40, with scores above 20 indicating the possibility of alcohol dependence.

Alcohol Expectancy Questionnaire

The Alcohol Expectancy Questionnaire (AEQ; Brown, Goldman & Christiansen, 1985) is a 120-item self-report questionnaire designed to assess positive expectations for moderate alcohol consumption. Participants are asked to indicate whether they agree or disagree with each statement based on their own personal beliefs (e.g., “Alcohol decreases muscular tension.”). This measure has six factors that were identified through factor analysis: global positive expectancies (α = .95), sexual enhancement (α = .89), enhancement of social and physical pleasure (α = .77), socially assertive personality changes (α = .89), relaxation or tension reduction (α = .82), and feelings of arousal or aggression (α = .27). The global positive expectancies scale was used in this study for analyses that included this measure.

Barrett Impulsivity Scale-11

The Barrett Impulsivity Scale (BIS; Stanford & Barratt, 1995) is a 30-item assessment instrument that reflects the domains of motor, nonplanning, and attentional impulsivity. Participants rate the frequency with which they experience each item using a Likert scale (1 = “rarely/never,” 2 = “occasionally,” 3 = “often,” and 4 = “almost always/always.”). A sample item: “I make up my mind quickly.” The BIS-11 has been shown to have adequate internal consistency in samples of college students ($\alpha = .82$) and substance abuse patients ($\alpha = .79$; Stanford & Barratt, 1995). The attentional and nonplanning scales were used in analyses that included this measure.

Measures of Decision Making

Iowa Gambling Task

A computerized version of the Iowa Gambling Task (IGT; Bechara et al., 1994, 2000) was used to explore participants’ decision making abilities. Participants were instructed to select a card from one of four decks of cards (A’, B’, C’ and D’) on each of 100 trials, with the goal of maximizing total winnings. Decks A’ and B’ are disadvantageous in that they are associated with larger immediate monetary gain but greater monetary loss, ultimately resulting in a negative balance. Conversely, decks C’ and D’ are characterized by smaller immediate gains but smaller ultimate losses, resulting in positive net gain. The total number of advantageous choices (selections from decks C’ and D’) minus disadvantageous choices (selections from decks A’ and B’) is computed to provide an index of net advantageous decision making. Higher net scores indicate better decision making.

Cups Task

A computerized version of the Cups Task (Levin & Hart, 2003; Levin, Weller, Pederson, & Harshman, 2007; Weller et al., 2007) was used to determine participants' decision making abilities as a function of whether they were presented with potential gains (i.e., reward) or potential losses (i.e., punishment). Participants were presented with a number of cups (2, 3, or 5), by which they could calculate their probability of winning (.50, .33, or .20, respectively). For example, if there were three cups the probability would be one-third. Participants chose between a sure gain of one quarter (riskless option) versus the potential to win "two quarters or no quarters" (risky option). The amount that a participant could win varied across trials; options included a potential to win "three quarters or no quarters" or "five quarters or no quarters." Thus, based on the combination of probability and amount to be won within the gain domain, some trials were risk advantageous (e.g., .33 x 5, .50 x 3, .50 x 5) and others were risk disadvantageous (e.g., .20 x 2, .20 x 3, .33 x 2); the riskless option (i.e., sure gain of one quarter) is the obvious better choice in the latter condition. The same procedure was repeated during loss trials, except that participants were presented with the option of losing "two (three or five) quarter(s) or no quarters," versus a sure loss of one quarter.

Participants completed a total of 54 Cups Task trials, comprised of three trials each of all possible combinations of probability (.20, .33, or .50), domain (gain or loss), and outcome magnitude (potential win/loss of 2, 3, or 5 quarters vs. sure win/loss of 1 quarter). The total amount of money won was displayed on the screen upon completion of all 54 trials.

For purposes of data analysis, the total number of risky choices for the gain domains and the loss domains were calculated. To determine a participant's willingness to take a risk when it is advantageous to do so (risk sensitivity), the total number of risk disadvantageous choices was subtracted from the total number of risk advantageous choices for the gain and loss domains. Higher scores on the variable of risk sensitivity are indicative of better decision making.

Delay Discounting Task

A computerized version of the Delay Discounting Task (DDT; Mitchell, 1999) was used to assess monetary discounting as a function of delay to reward. Participants were presented with two hypothetical monetary options and asked to indicate their preference between a "standard" and an "alternative." In each of the 138 trials, the standard was always a $10.00 option awarded after one of six delays (0, 7, 30, 90, 180 or 360 days). The alternative was one of 23 monetary values ($0.00; 0.25; 0.50-10.50 in $ 0.50 increments) offered now (i.e., no delay). For example, participants were asked to choose between options such as '$4.50 now versus $10.00 in 365 days.' Order of presentation was random so that items were not presented in ascending or descending fashion. K-values, which indicate the gradient of the discounting function, were computed for each participant (Mazur, 1987). Larger values indicate a greater preference for the immediate alternative.

Statistical Procedures

Analyses were conducted with growth curve analytic techniques (GCA; Raudenbush & Bryk, 2002) and the HLM 6 computer program (Raudenbush, Bryk & Congdon, 2004). GCA allows for a simultaneous, two-stage process. The first stage (Level 1) estimates a trajectory of change (growth curve) for a variable described by two parameters: intercept and slope. GCA provides tests of whether, on average, intercepts and slopes differ significantly from zero and whether there is significant variability in parameter estimates. Effects on each parameter of the trajectory are estimated simultaneously, such that effects on one parameter are estimated controlling for effects on other parameters. Time was measured as days since the midpoint between Time 1 and Time 3 for all analyses modeling the intercept as overall level of the outcome variable averaged across time. Time was entered as group mean centered so that the intercept would reflect the overall level of the outcome variable. Because of the complexity of GCA, the data analytic approach will be addressed separately for each aim.[2]

Missing data at the item level accounted for 0.12% of the data and were accounted for using the proportion estimation procedure. Post-hoc analyses were conducted using an online calculator (Preacher, Curran & Bauer, 2003) for all significant moderation effects such that simple effects were computed (a) at each level of dichotomous moderators, and (b) at 1 SD below the mean and at 1 SD above the mean for continuous moderators.

CHAPTER III

RESULTS

Descriptive Statistics

Participants were 136 first-year students (111 women, 25 men) with an average age of 18.12 years (*SD* = .33 months) at Time 1. When asked about family history of alcohol problems, 15.2% of the students reported that one or both of their parents had a problem with alcohol. On being asked to report on drinking behaviors during high school, negative consequences of drinking, and whether their drinking has changed since they have matriculated at the University of Iowa, over two-fifths of the students (42%) reported drinking at binge levels (i.e., five or more drinks for men, four or more for women) on a typical night of drinking during their senior year of high school. Most students (71.7%) regarded themselves as "regular drinkers" at Time 1; 17.1 years old was the average age of regular drinking onset (*SD* = .99). Nearly half (48.6%) of participants indicated that their drinking had increased since matriculating at the University of Iowa. Pre-college alcohol use and current consumption reported at Time 1 are shown in Table A1.

At Time 1, 52.2% of students met the criterion for past 30-day binge drinking. Of the total sample of men (*N* = 25), 72.0% met this criterion, as did 47.8% of all of the women in the sample (*N* = 111). Only 12 students (8.7%) reported that they had not consumed at least one drink of alcohol; 23.9% of the sample met criteria for frequent binge drinking. With regard to other risky behaviors, 14.4% of students smoked cigarettes on occasion and 2.9% smoked daily; 15.8% used recreational drugs on occasion (including misuse of prescription drugs) and 10.1% reported doing so on a daily basis. Smokeless tobacco use was much less common, with 2.2% reporting occasional use and 2.9% reporting daily use. No students endorsed daily gambling, but 14.4% of students indicated they gambled on occasion.

On average, binge drinking and frequent binge drinking increased over time (see Tables A2 –A4). At Time 2, 52.2% of participants reported drinking at binge levels in the past 30 days; at the final point of data collection, Time 3, 61.4% of students in the sample met criteria for binge drinking. At Time 2, 79.2% of the total number of men in the sample (*N* = 24) reported past 30-day binge drinking, as did 46.4% of women (*N* = 108). When measured at Time 3, 72.2% of the total number of men in the sample (*N* = 18) and 59.0% of women (*N* = 84) engaged in binge drinking within the past month. Frequent binge drinking increased at Time 2 (26.9%) and remained at a similar level at Time 3 (26.5%). Students experienced many negative consequences associated with alcohol use (see Table A5). Means and standard deviations for performance on decision making tasks are presented in Table A6.

Correlations

Correlations between variables at Time 1 are displayed in Table A7. Correlations between variables ranged from unrelated to large in size (*rs* = .001 to .72). Alcohol measures were sufficiently distinct to support the use of multiple indicators of drinking (*rs* = .68 to .72); measures of decision making were generally tiny to small in size (*rs* = .001 to .22) with one exception, which was the association between the Cups Task measure of overall risk taking for gains and losses (*r* = .62). Given that the correlations are relatively low, it is unlikely that there would be significant associations between predictors and the *overall levels* of the outcome variables; however, because growth curve analysis estimates trajectories of change over time, it is possible that there could be a significant association between predictors and *changes in* outcome variables over time.

Completers vs. Noncompleters

Participants enrolled in the study during the first five weeks of the fall semester, 2008; 136 students provided consent to participate and provided usable data. The retention rate at the second time point was 98.5% (N = 134); at Time 3, 75% of the original sample completed measures (N = 102). Despite effort to retain participants through email, text message, and voicemail reminders, 36 students (7 men, 29 women) did not complete all three time points. Independent samples t-tests revealed that gender differences were not associated with attrition from the study. Participants who completed Time 1 but not the final time point did not differ from participants who completed all time points on age of regular drinking, Greek affiliation, or alcohol consumption (i.e, AUDIT score, quantity of alcohol consumed, or binge frequency) at Time 1. Students who reported having at least one parent with an alcohol problem were marginally significantly less likely to complete the final time point, $t(132) = 1.81$, $p = .07$. Attrition did not differ between subjects based on performance on any of the decision making tasks at Time 1. Participants who did not complete all of the time points also did not differ from those who did completed the study on measures of impulsivity or alcohol expectancies as measured at the first time point.

Preliminary Analyses

Trajectories of Drinking over the First Year of College

A linear model of alcohol use was tested from the three longitudinal data points in the present study:

$$Y_{ij}\ (alcohol\ use) = \beta_{0j} + \beta_{1j}\,(Time) + r_{ij}$$

where Y_{ij} is alcohol use for individual *j* at Time *i*, β_{0j} is the intercept of individual *j* at Time 0 (defined as the overall or average level of alcohol use across the three time points in the present study), β_{1j} is the rate of linear change in alcohol use for individual *j* over time (i.e., slope), and r_{ij} is the residual variance in repeated measures for individual *j*, which is assumed to be independent and normally distributed. The linear model was then compared to a mean-and-variance model (in which alcohol use is modeled as fluctuating randomly around an individual's mean):

$$Y_{ij}\ (alcohol\ use) = \beta_{0j} + r_{ij}$$

The relative fit of the linear model compared to the mean-and-variance model was examined for each of the indicators of alcohol use presented above to identify the best-fitting baseline models.

Harmful Drinking. On average, harmful drinking, as measured by the AUDIT, *increased* systematically over time, $t(135) = 3.90$, $p < .001$. A comparison of the linear model to the mean-and-variance model suggested that the linear model provided a better fit for the data, $\chi^2\ (2) = 16.96$, $p < .001$. Accordingly, a linear model was specified for all subsequent analyses including harmful drinking as the outcome variable.

Drinking quantity. On average, drinking quantity did not change systematically over time, $t(135) = .92$, $p = ns$. A comparison of the linear model to the mean-and-variance model suggested that the mean-and-variance model provided a better fit for the data, $\chi^2\ (2) = 0.08$, $p > .50$. The mean-and-variance model was retained and used for all analyses in which drinking quantity was the outcome variable.

Binge drinking frequency. A linear model of binge drinking frequency was tested and showed that, *on average*, binge drinking frequency did not change systematically over time, $t(135) = .41$, $p = .68$; however, there was significant between-subject variability in the slope parameters, χ^2 (131) = 172.87, $p < .01$. The linear model was compared to a mean-and-variance model and the linear model was found to be a better fit for the data, χ^2 (2) = 11.29, $p < .005$. All subsequent analyses using binge drinking frequency as the outcome variable included a linear model.

Trajectories of Decision Making

A linear model of decision making was tested from the three longitudinal data points in the present study:

$$Y_{ij}\ (decision\ making) = \beta_{0j} + \beta_{1j}\ (Time) + r_{ij}$$

where Y_{ij} is the performance on a decision making task for individual *j* at Time *i*, β_{0j} is the intercept of individual *j* at Time 0 (i.e., the overall or average performance on decision-making tasks across 3 time points), β_{1j} is the rate of linear change in decision making performance for individual *j* over time (i.e., slope), and r_{ij} is the residual variance in repeated measures for individual *j*, which is assumed to be independent and normally distributed. The linear model was compared to a mean-and-variance model (in which performance on decision-making tasks is modeled as fluctuating randomly around an individual's mean):

$$Y_{ij}\ (decision\ making) = \beta_{0j} + r_{ij}$$

The relative fit of the linear model compared to the mean-and-variance model was examined for each of the indicators of decision-making to identify the best-fitting baseline models.

Delay Discounting Task. On average, decision making abilities did not change systematically over time, $t(135)=.74$, $p = .46$. The mean-and-variance model proved to be a better fit for the data than a linear model, χ^2 (2) = 5.14, $p = .08$, and was specified for all subsequent analyses using the Delay Discounting Task as an outcome variable.

Cups Task. The linear model was tested for each of four indicators of decision making in the Cups Task, including overall risk taking for gains/losses and sensitivity to gains and losses. There was no systematic change in scores of risk taking for gains over time, $t(135) = -.28$, $p = .78$. The mean-and-variance model was a better fit for the data than a linear model, χ^2 (2) = 4.46, $p = .11$. On average, risk taking for loss trials decreased over time, $t(135) = -2.16$, $p=.03$. The linear model proved to be a better fit for the data, χ^2 (2) = 379.32, $p < .001$. There was no systematic change over time (on average) for either sensitivity to gains, $t(135) = -.56$, $p = .58$, or losses, $t(135) = -.008$, $p = .99$. Relative to a linear model, a mean-and-variance model was a better fit for sensitivity to gains, χ^2 (2) = 1.86, $p > .50$, and sensitivity to losses, χ^2 (2) = 1.91, $p > .50$.

Trajectories of Negative Consequences

A linear model of reported negative consequences associated with drinking was tested from the three longitudinal data points in the present study:

$$Y_{ij}\ (negative\ consequences) = \beta_{0j} + \beta_{1j}\,(Time) + r_{ij}$$

where Y_{ij} is the number of negative consequences for individual j at Time i, β_{0j} is the intercept of individual j at Time 0 (i.e., the overall or average number of negative consequences across 3 time points), β_{1j} is the rate of linear change in negative consequences for individual j over time (i.e., slope), and r_{ij} is the residual variance in repeated measures for individual j, which is assumed to be independent and normally distributed. On average, negative consequences associated with alcohol use increased systematically over time, $t(135) = 2.30$, $p = .02$.

The linear model was compared to a mean-and-variance model (i.e., in which negative consequences are modeled as fluctuating randomly around an individual's mean:

$$Y_{ij}\ (negative\ consequences) = \beta_{0j} + r_{ij}$$

The linear model provided a better fit for the data than the mean-and-variance model, $\chi^2(2) = 21.77$, $p < .001$. Accordingly, a linear model was specified for all subsequent analyses including negative consequences as the outcome variable.

Aim 1: Decision Making as a Predictor for Alcohol Use

Decision Making Predicting Alcohol Use

The following equations were specified to examine predictors of each indicator of alcohol use (i.e., harmful drinking, drinking quantity, binge drinking frequency) with each measure of decision making (i.e., IGT, DDT, Cups Task) entered separately as grand-centered at Level 2:

Level 1: Y_{ij} (Alcohol use) = $\beta_{0j} + \beta_{1j}$ (Time) + r_{ij}

Level 2: β_{0j} (Average Levels of Alcohol Use) = $\gamma_{00} + \gamma_{01}$ (decision making at Time 1) + μ_{0j}

β_{1j} (Changes in Alcohol Use) = $\gamma_{10} + \gamma_{11}$ (decision making at Time 1) + μ_{1j}

Predictors of harmful drinking. Performance on the Cups Task measure of sensitivity to risk for the gains domain significantly predicted overall levels of harmful drinking, $t(134) = 3.20$, $p = .002$. To the extent that individuals made more risk-advantageous choices at Time 1, they had higher levels of harmful drinking averaged across time. The Cups Task measure of total risk-taking for the gains domain also significantly predicted overall levels of harmful drinking, $t(134) = 2.08$, $p = .04$. Individuals who made more risky choices at Time 1 in the gains domain had higher levels of harmful drinking on average across time. Average scores of harmful drinking were not significantly predicted by performance on the IGT, the DDT, or Cups Task indexes of sensitivity to losses or total number of risky choices for losses. Further, decision-making did not significantly predict changes in harmful drinking over time. Results are reported in Table A8.

Predictors of Drinking Quantity. Performance on the IGT significantly predicted the overall number of drinks consumed during a drinking occasion (averaged across time), t (134) = 2.65, $p < .01$. To the extent that individuals evidenced more effective decision-making on the IGT at Time 1, they reported consuming a greater number of alcoholic beverages on a drinking occasion (averaged across time). Performance on the other measures of decision-making did not significantly predict drinking quantity. See Table A9 for results.

Predictors of Binge Drinking Frequency. Sensitivity to gains in the Cups Task was a significant predictor of changes in binge drinking frequency over time, t (134) = 2.67, $p = .01$. Individuals who made risky choices for gains when it was advantageous to do so at Time 1 had a steeper increase in frequent binge drinking across time. Frequent binge drinking (overall levels and changes in drinking over time) was not predicted by any other measures of decision making. Results are presented in Table A10.

Alcohol Use Predicting Decision Making

To account for the possibility that poorer decision-making may be a consequence of alcohol consumption, Time 1 alcohol use was considered as a predictor for each of the decision-making indices. The following model was specified to examine predictors of each measure of decision making (i.e., IGT, DDT, Cups Task), with each indicator of alcohol use (i.e., harmful drinking, drinking quantity, binge drinking frequency) entered separately as grand-centered at Level 2:

Level 1: Y_{ij} (Decision Making) = β_{0j} + β_{1j} (Time) + r_{ij}

Level 2: β_{0j} (Average Levels of Decision Making) = γ_{00} + γ_{01} (alcohol use at Time 1) + μ_{0j}

β_{1j} (Changes in Decision Making) = γ_{10} + γ_{11} (alcohol use at Time 1) + μ_{1j}

All results are reported in Table A8-A10. Alcohol use at Time 1 did not predict average performance on the DDT, the total number of risky choices for the loss domain (overall levels and changes over time), or sensitivity to gains or losses averaged across time. However, harmful drinking was a marginally significant predictor of total number of risky choices for the gain domain, t (134) = 1.77, p = .08. To the extent that individuals engaged in more harmful drinking at Time 1, they made more risky choices in the gain domain of the Cups Task (averaged over time).

Effect Size Comparisons

To establish temporal precedence of risk factors, the effects sizes for (a) the associations between decision-making at Time 1 and alcohol use across time and (b) the corresponding associations between alcohol use at Time 1 and performance on measures of decision-making across time were compared. The effect size of overall risk taking for gains at Time 1 predicting overall levels of harmful drinking (effect size r = .18) did not differ significantly from the effect size for harmful drinking at Time 1 predicting overall levels of risk taking for gains (effect size r = .15), Z = 0.27, *n.s.* Although making more risky choices for gains at Time 1 significantly predicted more harmful drinking, the results do not suggest temporal precedence. As can be seen in Tables A8-A10, no other effect sizes were significantly different from one another.

Aim 2: Moderators of the relationship between decision making and drinking

To examine whether the associations between Time 1 decision making and trajectories of alcohol use varied as a function of family history, drinking history, gender, trait impulsivity, or alcohol expectancies, I specified the same equations as in Aim 1 with Time 1 decision-making (i.e., DDT, IGT, Cups Task) entered as a predictor of overall levels of alcohol use and changes in alcohol use (when applicable). In addition, each moderator and the corresponding interaction term were entered into each of the Level 2 equations. For example, for the IGT predicting harmful drinking, with gender examined as a potential moderator of this relationship, the following model was specified:

Level 1: Y_{ij} (harmful drinking) = β_{0j} + β_{1j} (Time) + r_{ij}

Level 2: β_{0j} (Overall Levels) = γ_{00} + γ_{01} (IGT) + γ_{02} (moderator) + γ_{03} (interaction term) + μ_{0j}

β_{1j} (Changes over Time) = γ_{10} + γ_{11} (IGT) + γ_{12} (moderator) + γ_{13} (interaction term) + μ_{1j}

Harmful drinking

In general, moderation terms were not significant for the associations between each of the indicators of decision-making and harmful drinking (*t*s ranged from 0.23 to 1.82) with two exceptions. First, family history of alcohol problems was a significant moderator of the association between Time 1 scores on the Cups Task (sensitivity to risk for loss scale) and harmful drinking averaged across time, t (132) = -1.96, p = .05. Post-hoc analyses indicated that the simple effects of sensitivity to risk for loss on harmful drinking was marginally significant for persons without a family history of alcohol problems, γ = -0.88, p = .06, but was not significant for persons with a family history of alcohol problems, γ = 0.07, p = *ns*.

The association between sensitivity to risk for loss and average drinking levels was stronger (more negative) at higher levels of positive alcohol expectancies, t (132) = -

2.23, p = .03. Post-hoc analyses revealed that the simple effects of sensitivity to risk for loss on average drinking levels were significant at 1 SD below the mean of the AEQ, γ = -22.49, p = .03, and at 1 SD above the mean, γ = -28.80, p = .03.

Drinking Quantity

In general, moderation terms were not significant when drinking quantity was entered as the outcome variable (*t*s ranged from -0.04 to 1.93), but there was one exception. The BIS nonplanning scale was a significant moderator of the association between Time 1 scores on the Cups Task (sensitivity to risk for gains scale) and drinking quantity averaged across time, t (132) = 2.05, p = .04. The association between sensitivity to risk for gains and average drinking levels was stronger (more positive) at higher levels of BIS nonplanning. Post-hoc analyses revealed that the simple effects of "sensitivity to risk for gains" at average drinking levels were significant at 1 SD below the mean of the BIS, γ = 5.15, p = .04, and at 1 SD above the mean, γ = 7.77, p = .04.

Binge Drinking Frequency

Several moderation terms were significant when binge drinking frequency was entered as the outcome variable. There was significant moderation for performance on the IGT at Time 1 and binge drinking frequency, t (132) = -2.39, p = .02. Follow-up analyses revealed that the simple effect was only significant for persons without a family history of alcohol problems, γ = -0.52, p = .02, not for persons with a family history of alcohol problems, γ = 0.01, p = *ns.*

Family history of alcohol problems also significantly moderated the association for the Cups Task measures of sensitivity to risk for gains, t (132) = 2.03, p = .04 and losses, t (132) = 2.48, p = .01, predicting average frequency of binge drinking across time. The simple effect between sensitivity to risk for losses was only significant for persons without a family history of alcohol problems, $\gamma = 0.39$, $p = .01$, not for persons with a family history of alcohol problems, $\gamma = -0.06$, $p = ns$. The simple effect for sensitivity for gains was significant for persons with, $\gamma = 0.10$, $p = .01$, and without, $\gamma = 0.28$, $p < .01$, a family history of alcohol problems.

The BIS scale of nonplanning significantly interacted with the DDT to predict frequent binge drinking over time, t (132) = -2.05, $p = .04$. The association between the DDT and frequency of binge drinking was stronger (more negative) for individuals scoring higher on nonplanning. The simple effect for this association were significant at 1 SD below the mean level of nonplanning, $\gamma = -9.15$, $p = .05$, and 1 SD above the mean, $\gamma = -13.62$, $p = .04$.

Aim 3: Covariation between drinking and negative consequences over the first year of college

Correlations between negative consequences and indicators of alcohol use were generally small; they are presented in Table A11. Based on preliminary baseline analyses, the following linear model of negative consequences was specified with alcohol use entered as a time-varying covariate:

$$Y_{ij}\ (negative\ consequences) = \beta_{0j} + \beta_{1j}\,(Time) + \beta_{2j}\,(alcohol\ use) + \ + r_{ij}$$

where Y_{ij} is negative consequences use for individual j at Time i, β_{0j} is the intercept of individual j at Time 0 (i.e., the overall or average level of negative consequences use across three time points), β_{1j} is the rate of linear change in negative consequences for individual j over time (i.e., slope), β_{2j} represents the extent to which changes in alcohol use are associated with changes in negative consequences over time, and r_{ij} is the residual variance in repeated measures for individual *j*, which is assumed to be independent and normally distributed.

As presented in Table A12, rates of change in harmful drinking were significantly associated with rates of change in negative consequences over time, $t(135) = 4.89$, $p < .01$. To the extent that harmful drinking increased over time, so did negative consequences of drinking. Rates of change in drinking quantity were also significantly associated with rates of change in negative consequences, $t(135) = 3.80$, $p < .01$. To the extent that drinking quantity increased over time, negative consequences increased more rapidly. Finally, rates of change in number of binge drinking episodes were associated with rates of change in negative consequences over time, $t(135) = 5.13$, $p < .01$. To the extent that binge drinking increases over time, so did negative consequences. In sum, consistent with the study's hypotheses, to the extent that there was an increase in drinking over the year, as measured by each of three indicators of alcohol use, there was also an increase in alcohol-related negative consequences.

Aim 4: Ecological Validity of Decision-Making Tasks

Correlational analyses were used to determine whether measures of decision-making are associated with self-reported behavioral consequences of drinking. A significant association would provide evidence that decision-making tasks have ecological validity in a sample of college student drinkers. Contrary to expectation, none of the decision-making tasks at Time 1 were significantly associated with the total number of negative consequences experienced at any of the three time points (see Table A13).

CHAPTER IV

DISCUSSION

Although there is clear evidence that persons with long histories of heavy alcohol use perform more poorly on measures of cognitive functioning (e.g., Bates et al, 2002; Giancola & Moss, 1998), the research is somewhat equivocal with respect to college student drinkers. Some studies provide evidence of impairment in specific cognitive abilities in college student drinkers (e.g.,Giancola et al., 1996) while others do not (e.g., Blume et al, 2000; Sher et al., 1997); none have shown that any identified deficits persist beyond the college years (Wood et al., 2002). Surprisingly, only a single study examined the relationship between heavy drinking and the cognitive ability of decision making, reporting an association of this nature only for students with the longest and heaviest trajectory of drinking (Goudriaan, Grekin & Sher, 2007). None investigated the role of decision making as a risk factor for heavy drinking during the first year of college. That was the primary aim of the present study.

To achieve this aim, it was first necessary to determine whether drinking increased during the first year of college for participants in our sample. Drinking by participants did increase, although there was considerable variability in alcohol use trajectories as a function of how the drinking was assessed. Indicators of alcohol use that measured harmful drinking (via the AUDIT) and counts of binge drinking frequency demonstrated linear increases over time. However, average number of drinks consumed on an occasion did not change over time. Although students increased the frequency with which they consumed alcohol at levels that met criteria for binge drinking, and also showed increases in associated risky behaviors, they did not necessarily consume a greater number of drinks across time. It appears that students went out more frequently as the year progressed but generally consumed the same amount of alcohol on each occasion throughout the year. This is a novel finding, even though our results generally replicate previous research identifying the first year of college as a critical period in which many students increase their drinking (Hartzler & Fromme, 2003). Hence, they provide a necessary basis for examining risk factors that predict increases in amount and frequency of drinking.

Decision making abilities, which were examined as a primary risk factor for linear increases in drinking, remained largely stable over time. Though this was mainly an exploratory hypothesis, the findings are not surprising given Levin et al.'s (2007) demonstration of three-year stability on Cups Task measures of overall risk taking for gains and losses in young children and adults. Measures of decision making in the present study generally were not correlated with one another, however, suggesting that each measure assessed a different facet of decision making and thereby supporting inclusion of each in the present study.

Decision Making as a Risk Factor for Drinking

Despite our hypotheses to this effect, findings from this study do not provide strong evidence that impaired decision making represents a substantial risk factor for increased drinking during the first year of college. The few significant associations between decision making ability and drinking rates were not robust and had very small effect sizes. Moreover, no consistent association was found between any specific measure of decision making and any indicator of alcohol use. Given that correlations between measures of decision making and alcohol use were generally non-significant, this is not surprising. Although the lack of a significant association between drinking and impaired cognition in college students is not necessarily at odds with the literature (e.g., Giancola & Tarter, 1999), the finding that, in several instances, *better* decision making at Time 1, at the inception of the study, predicted *increased* drinking in the first college year of college was surprising – and difficult to explain. For this reason, other established risk factors for drinking that significantly interacted with decision making at Time 1 to predict trajectories of drinking were examined in order to clarify the nature of the association between drinking and decision making.

Interaction between Decision Making and Established Risk Factors for Drinking

Risk factors bearing a robust relationship to drinking by college students (i.e., family history of alcohol problems, drinking history, gender, alcohol expectancies, and impulsivity) were chosen for inclusion in this study. Interactions with decision making and drinking were generally non-significant and, again, the few significant associations found varied depending on predictor and outcome variable. Family history of alcohol problems was the risk factor that most often interacted significantly with a measure of decision making to predict an increase in drinking. Notably, these associations also had small effect sizes and simple effects were typically not significant for persons with a significant family history of alcohol problems. Instead, the association between measures of decision making and drinking was only significant for persons without a family history of alcohol problems, which was surprising. However, alcohol consumption did not significantly differ between students with and without a significant family history at any time point, which is likely due in part to the small number of students reporting a family history of alcohol problems (16% of the sample), and may explain why the simple effect was not significant for this group.

Given that male college students consistently drink more than females (e.g., O'Malley & Johnston, 2002, Wood et al., 2004, Greenbaum et al., 2005), it was unexpected that the association between drinking and decision making did not differ for men and women. Within the present study, 72% of males reported drinking at binge levels in the past 30 days at Time 1 compared to 47.8% of all female participants. This difference is striking, but given the small number of males enrolled in the study (N = 25), it is likely that there was insufficient power to detect moderating effects of gender for the association between drinking and decision making. It is also possible that the males who consented to participate in this study were more conscientious than the males who did not, which may further limit the generalizability of findings.

Covariation of Drinking and Negative Consequences

It could well be argued that heavy college student drinking is normative and thus not necessarily indicative of bad decision making. The literature defines poor decision making as repeatedly engaging in the same behavior despite negative consequences (Byrnes, 2002), so it would appear that, for students in this study, their heavy, consequential drinking is associated with poor decision making. However, it is also possible that college students do not place a negative valence on these consequences, and instead, see them as positive because they are so clearly an aspect of the college student role at the University of Iowa. For example, although unplanned sexual activity is regarded as a negative consequence in the literature (Wechsler et al., 1994), many students might view this as a positive consequence of drinking because so many students report having experienced it. Getting behind in schoolwork or having a hangover, which might seem to be undesirable outcomes of binge drinking instead might be regarded by students as rites of passage and not viewed negatively. All of this being the case, then drinking may be reinforced (or at least not punished) by these consequences, thereby rendering them poor indicators of impaired decision making in a college sample.

Several studies have considered college students' experience of negative versus positive consequences of drinking. Park (2004) asked students to rate the frequency with which they experience negative (e.g., "do something you later regretted") and positive (e.g., "felt more sexy") consequences. Results showed that although students reported encountering both types of consequences, they reported experiences with a positive valence as more frequent, more extreme, and more likely to influence future drinking behavior. In a similar vein, Mallett, Bachrach, and Turrisi (2008) noted that while researchers assume various consequences of drinking are perceived negatively by students, empirical investigations have not confirmed the legitimacy of the assumption. In their study, students were provided with a list of consequences of drinking and asked to reflect on the last time they experienced them and to rate how positive or negative they were, using a 5-point Likert scale. The investigators reported that several consequences presumed to be negative by researchers, such as having a hangover or waking up in someone else's bed after a night of drinking, were viewed more positively than negatively by participants. Although direct comparisons cannot be made to the present study because Mallett et al. (2008) did not use the same composite of negative consequences, their findings provide clear evidence of a disparity between how students and researchers perceive outcomes of drinking.

Students in the present study were not asked to rate the extent to which they regarded behavioral outcomes as negative. However, they completed a self-report of alcohol expectancies, which measures beliefs about the anticipated global positive effects of drinking. Correlational analyses revealed that students who endorsed more positive expectancies for alcohol at Time 1 also reported more drinking on all indicators of alcohol consumption (*r*'s ranged from 0.27 to 0.52), as well as experiencing a *greater* number of negative consequences of drinking ($r = 0.27$). This finding provides support for the view that, despite experiencing a large number of alcohol-related consequences that significantly covaried with drinking, students largely regard alcohol as likely to affect their experience in positive ways. In addition, students' anticipated cumulative GPA was in the B range at the end of the first ($M = 3.25$, $SD = .41$) and second ($M = 3.19$, $SD = .58$) semesters, suggesting that despite drinking at high levels, most were able to maintain adequate grades. This provides more support that drinking may not have been a punishing experience, since this group apparently persevered in their school work despite their drinking behavior.

Ecological Validity of Measures of Decision Making

Another aim of the present study was to ascertain whether measures of decision making have ecological validity in this sample. Whereas studies assessing the ecological validity of the *IGT* for persons with lesions in the VMPC have shown an association with real world deficits in decision making (Verdejo-Garcia et al., 2006), data from the present study did not show a significant association between measures of decision making and negative consequences of drinking. This is an important finding because it indicates that, although some students performed poorly on laboratory tasks, the impairment did not translate into deficits in the real world associated with drinking. As a result, these tasks will not allow us to make predictions about whether students in this sample will modify drinking behavior based on the consequences of their drinking, and likely will not be helpful in identifying at risk students. Although no other studies have considered ecological validity of decision making tasks in a college population, those that have looked at other executive functions have reported conflicting results. Whereas one research group (Giancola et al., 1996) reported a significant association between executive functioning and severity of consequences of alcohol use experienced by students, another failed to identify such a significant relationship (Whitney et al., 2006). That these measures do not have ecological validity in this sample has important implications for understanding the lack of results.

Accounting for Null Findings

Studies demonstrating an association between impaired performance on the Iowa Gambling Task and substance dependence (e.g., Bechara et al., 2001), coupled with speculation that deficits in decision making may presage substance dependence (e.g., Bechara, 2005; Noel et al., 2006), led to the expectation that poorer performance on measures of decision making would be a risk factor for increased drinking during the first year of college. However, the results of the present study are generally not supportive of these hypotheses. The absence of significant results, and occasional findings at decided variance from predictions, are difficult to reconcile. One of the first concerns is whether there was significant between-subject variability. If performance on measure of decision making did not vary between participants, and if students reported similar drinking trajectories over the first year of college, then it would not make sense to examine either as predictor or outcome variables. However, preliminary analyses confirmed that there was significant variation on all measures, indicating that they would be able to detect associations between these variables if indeed they existed.

Participants' mean net scores on the Iowa Gambling Task were lower than would be expected given their age, which may be reflective of insufficient effort on the task. Research has shown that most healthy adults have *IGT* net scores over 20 (Bechara, Damasio & Damasio, 2000; Mazas, Finn & Steinmetz, 2000) and healthy 14-17 year-olds have average net scores of around 13 (Hooper, Luciana, Conklin & Yarger, 2004). The average net score in this sample, which had a mean age of 18.12 years old, was only 11.25. Although this score is surprisingly low, it is important as well to point to a very large standard deviation (*SD* = 29.53) associated with the score: if an association existed between performance on this measure and drinking, there appears to be adequate variability among participants to identify it.

In contrast to their surprisingly low *IGT* net scores, participants evidenced remarkably good decision making on the *DDT*, as indicated by *lower* k-scores. Scores on the *DDT* are typically within the range of 0-5, but participants in this sample had a low mean (average *M* across time points = .17) with a relatively small standard deviation (average *SD* across time points = .78). As compared to the *IGT*, which measures ability to evaluate risk under ambiguity, the *DDT* captures impulsivity and willingness to delay gratification. Although higher scores were expected to predict increased drinking, the association between *DDT* scores and drinking was not significant, likely because students performed so well on the instrument.

As noted in the Methods section, this study included multiple measures of decision making. Of them, the *Cups Task* yielded the most consistent measures associated with changes in drinking over time. Specifically, overall risk taking for *gains* and sensitivity to risk for *gains* on the *Cups Task* were most consistently associated with changes in drinking over time. Means and standard deviations of these measures were typical of those observed previously in students from this university (see Table A6; Figlock & Nathan, unpublished).

Perhaps the most perplexing of the present study's findings is that in some instances *better* decision making was associated with *increased* drinking during the first college year. Specifically, willingness to make risky choices on the *Cups Task* to achieve gains when it was advantageous to do so, believed to be indicative of better decision making, was associated with several indices of increased drinking. Given the possibility that students may view several alcohol-related consequences positively, or at least neutrally, rather than negatively, perhaps they regard drinking as a calculated risk likely to result in a favorable outcome. Goldberg and colleagues (2002) demonstrated that, among young adolescents, the accuracy of predicting drinking was greatly increased when perceived benefits were included in the model. They note that whereas researchers typically label drinking as irrational, if we account for benefits, drinking may not be reflective of poor decision making. In addition, it has widely been speculated that adolescents and young adults feel invulnerable to risk; however, research provides little support for this hypothesis (e.g., Steinberg, 2007). Instead, adolescents' estimates of the likelihood of experiencing serious risk behaviors are typically similar to estimates provided by adults (Beyth-Marom, Austin, Fischhoff, Palmgren & Jacobs-Quadrel, 1993). Importantly, adolescents and college-aged students are more likely to partake in these risks than adults (Steinberg, 2007), suggesting that while adolescents accurately perceive risk, they view the risks and associated consequences as less significant and so choose to engage in the behavior (Millstein & Halpern-Felsher, 2002).

In our attempt to understand these unexpected findings, it is important to note that, although more than half of the students in our sample reported binge drinking during the preceding 30 days, prevalence of binge drinking in the sample overall was substantially lower than has typically been observed in studies of drinking by students from this university. Whereas approximately 68-70% of students report past 30 day binge drinking at this university (Nathan, 2003; Wechsler, unpublished), binge drinking rates in this sample ranged from 52.2% to 61.4% across time points. One explanation may be that this group of students was particularly conscientious since, to be eligible for participation in the research, students had to be sufficiently motivated by the course research requirement to volunteer within the first five weeks of their first semester on campus for a year-long study. Moreover, to successfully complete the study and have their data included in all analyses, participants were required to provide data at all three time points. To this end, attrition rates during the study were relatively low (26.1%). At the same time, conscientiousness does not preclude sensitivity to social pressure: research shows that most college students drink more in contexts where drinking is normative (Knee & Neighbors, 2002). If more than 50% of students in this sample consistently met criteria for binge drinking, binge drinking is unlikely to reflect faulty decision making. Steinberg (2007) proposed that conventional decision making models may not be the best way to conceptualize risk in adolescents, instead suggesting that psychosocial factors, such as poor resistance to peer pressure, might undermine otherwise competent decision making. That students in this sample share a common environment in which binge drinking rates are among the highest in the nation almost certainly influenced their own consumption patterns. Perhaps heavy drinking is so embedded and normative in the social fabric of this university that it is more influential—accounts for a greater part of the variance associated with drinking—than impaired decision making or other risk factors.

It is appropriate to ask whether students in this sample drank at levels that would be expected to result in cognitive impairment. Although the study's primary hypothesis was that deficits in decision making would influence heavy drinking, the reverse hypothesis was also considered: Does heavy drinking lead to impaired decision making? The latter relationship was never significant. This negative finding is not surprising. Parsons and Nixon (1998) concluded that, among social drinkers, cognitive impairment was most consistently observed in drinkers who consumed 5-6 standard drinks or more a day. By contrast, typical students in the present study reported drinking an average of four drinks on a single occasion approximately five days a month, and no students reported daily consumption. Thus, although students in this study drank at elevated levels considered harmful by researchers, parents, and college administrators, they did not appear to drink at levels high enough to result in impaired decision making.

Strengths and Limitations

There were several positive results from the present study. First, to the best of the author's knowledge, this is the first study that considered impaired decision making as a risk factor for drinking in a college sample. Use of a longitudinal design at a time when drinking is known to increase for many students (during the first year of college) was intended to prospectively identify students at risk for heavy drinking during this critical period and thereby to move beyond cross-sectional associations. Second, aims were pursued in a relatively homogenous, high-risk sample of first year college students. Third, whereas most studies assessing college student drinking have used categorical measures of binge drinking, the present study used statistical analyses that accommodated continuous measures of predictor and outcome variables. This is notable, since transforming a continuous variable into a categorical variable can obscure important variability, making it undesirable for the most part to analyze data in this way. Fourth, use of multiple indicators of decision making allowed for an exploration of the impact of unique facets of decision making (i.e., decision under risk vs. ambiguity; impulsivity) in influencing risky drinking. Fifth, all variables were assessed at multiple time points, which facilitates examination of *changes* in drinking over time, in addition to overall levels of drinking. Sixth, this study included an investigation of whether measures of decision making had ecological validity in this sample.

Despite its strengths, the study was not without limitations. First, students in this sample did not report drinking at levels typically observed in students at this university. As a consequence, the possibility that students underreported consumption cannot be ruled out. However, this possibility is of less concern since the study's statistical analyses modeled *change* in drinking across time, and most indicators of drinking demonstrated linear increases. In other words, even if students underreported consumption, there nonetheless appears to have been sufficient linear increase to enable reliable predictions by target variables. Second, although conducting the initial assessment within the first month of the semester conferred a number of methodological advantages, participants that volunteered for the study might have been especially conscientious and not necessarily representative of other first year students. Third, all participants were recruited from the Elementary Psychology subject pool and were mostly female; both might have limited the generalizability of findings. Thus, replicating the study with students with more diverse academic interests and a sample that included more males might yield a different pattern of results. Fourth, students were not followed beyond their first college year, so it is not possible to know whether trajectories of drinking consistent with diagnostic criteria for substance dependence might eventually emerge for individuals with decision making deficits. Fifth, this study included many analyses, although few significant findings emerged, so it must be noted that the few significant findings could be attributed to Type I error. Sixth, although analyses based on data collected at Time 1 failed to show a difference between students that completed the study and those who did not, it is possible that students who attrited were the ones who became heavier drinkers over the course of the year.

Implications and Future Directions

The study's results generally provided little support for the hypothesis that impaired decision making is a risk factor for drinking during the first year of college. Nonetheless, this study represents a worthwhile contribution to the growing literature on cognitive functioning and drinking in that this potentially important association has not previously been explored. Moreover, the absence of significant findings should not be taken as conclusive evidence that drinking is not associated with impaired cognition or harmful outcomes in college students. Instead, it may be that, for first year college students, factors other than decision making, notably, the pressure to fit into a campus in which heavy drinking is normative, exert a stronger influence on drinking.

The possibility that decision making deficits predict increased drinking for those students with trajectories that continue to escalate over time could best be answered by following students for the duration of their undergraduate education. The vast majority of students in the present study (79.0%) reported being "regular drinkers" for a year or less. This finding is important, given that Goudriaan et al. (2007) reported a significant association between performance on the *IGT* and heavy drinking only for students who drank the heaviest, and most consistently, over the two-year duration of their study. Again, this suggests the importance of following students over a longer period of time to determine for whom decision making abilities predict heavy drinking that persists beyond the first year of college. That is, while it may be normative to experiment with alcohol during the first college year, drinking associated with impaired decision making may be something different.

To the extent that it is possible, future studies assessing risk for drinking during college should aim to assess decision making abilities *prior* to initiation of drinking behavior. Initial assessment during summer orientation, before the first college year begins, would represent a methodological advancement. It is possible that important premorbid differences in decision making abilities were obscured in the present study since many students had already begun drinking by the first point of data collection. A maximally informative design would include initial assessment of drinking and decision making at the beginning of high school, continuing throughout college, as this prospective design would permit more definitive conclusions about causality.

Future studies examining the association between drinking and decision making in college students should ensure that males are adequately represented in the sample. If sufficient funding is available, this could be achieved by expanding course recruitment beyond Elementary Psychology courses, which are especially popular with female students. It would also be useful to ensure that the sample was comprised of an adequate number of students with a family history of alcohol problems, so that the contribution of genetic liability to these issues could be more carefully analyzed.

Future research examining an association between decision making and heavy drinking in the collegiate population should take care to ensure that chosen consequences are viewed negatively by students, in light of findings that suggest participants in this study may not have always placed a negative valence on such consequences identified by researchers. This goal could be achieved by including a list of consequences and asking students to rate the extent to which they regard each as positive or negative. Inclusion of items rated by students as negative could then be used in analyses to provide evidence of the ecological validity of the decision making measures. Further, the extent to which students experience positive outcomes of their drinking, which may reinforce drinking behavior, should also be considered in future research studies.

While the *Iowa Gambling Task* (*IGT*) has been considered one of the most valid indicators of decision making, unfortunately, it is not appropriate in repeated administrations. Although it should be included in future studies examining the consequences of faulty decision making as a measure of risk, it will not be useful in studies seeking to determine whether heavy drinking is a risk factor for impaired decision making over time, since this design would require repeated administration of the instrument.

Although the *Delay Discounting Task (DDT)* was not a reliable predictor of increased drinking in this sample, it assesses a unique facet of decision making, and an association with substance dependence has been demonstrated in clinical samples. Thus, it seems premature to conclude that this decision making facet would not be associated with college student drinking. Hence, future exploration is warranted.

The *Cups Task* measures of risk taking for the gains domain emerged as the most consistent indicator of future drinking behavior and should be included in future studies. This task has the additional benefit of allowing for repeated administration. If funding is available, motivation on the *Cups Task* could be enhanced by awarding participants with cash based on their earned winnings, as has been done with other samples (e.g., Levin et al., 2007; Weller et al., 2007).

The present study included three measures of drinking behavior: an objective, validated self-report measure of harmful drinking (*AUDIT*) and two measures commonly used in the literature on college student drinking (drinking quantity and binge drinking frequency). The *AUDIT* and binge drinking frequency demonstrated significant linear increases over time and were more closely associated with measures of decision making. Although the measure of average number of drinks consumed on a single occasion is useful for categorizing students that meet criteria for binge drinking, it was uninformative in this study when assessing especially problematic drinking, since a “binge” style is quite normative on this campus. The *AUDIT* and the measure of binge drinking frequency, by contrast, seem to be more likely to reflect problematic drinking that escalates beyond that which is typical of first-year students and, as a result, more useful in analyses of decision making.

Conclusion

The present study aimed to determine whether impairment on neuropsychological measures of decision making predicts increased drinking during the first year of college. A secondary aim was to determine the extent to which established risk factors for drinking interact with performance on these measures to predict drinking. Results of the present study did not provide support for a robust association between any of these measures and indices of drinking behavior. The few significant associations that were identified consistently established temporal precedence of decision making predicting drinking, while the reverse association was never significant, thus providing some support for the belief that impaired decision making may precede harmful drinking. Further exploration of this relationship, then, is clearly warranted. Future studies with methodological designs that can address causality are especially important.

While the present study demonstrated that drinking and negative behavioral consequences of drinking increased during the first year of college, a significant association between performance on measures of decision making and negative consequences of drinking was not observed, suggesting that these measures did not have ecological validity in this sample. Although the latter finding was not consistent with expectation, it underscores the importance of ensuring that behavioral outcomes are regarded negatively by students, if we are to fully understand the association between drinking and decision making among college students.

In sum, this study employed a rigorous methodological and statistical design in a relatively homogeneous sample of first year students attending a university with one of the highest binge drinking rates in the nation. It contributes to the literature on cognitive functioning and drinking among college students, which typically does not demonstrate significant impairment among drinkers. However, continued study with the suggested methodological improvements holds great promise to provide a clearer understanding of this association.

NOTES

1. The Cups Task and Delay Discounting Task are not susceptible to practice effects, as probabilities are fully disclosed and subjects do not need to learn deck contingencies. There is some concern about repeated administration of the IGT, as performance in healthy controls has been shown to improve at one month re-test (Bechara et al., 2000); if statistical analysis indicates that time accounts for differences in performance in the present study, the IGT will not be included in stability analyses of decision making.

2. Data analytic plan for each aim.
<u>Aim 1: To determine whether decision making is a risk factor for drinking over the first year of college.</u>

Baseline models were examined to describe the trajectory of drinking in this sample of first year students. I expected systematic linear escalation in alcohol use over the first year of college, and will test a linear model of drinking across the three time points: Y_{ij} *(alcohol use)* $= \beta_{0j} + \beta_{1j}$ *(Time)*$+ r_{ij}$, where Y_{ij} is the alcohol use for individual j at Time i, β_{0j} is the intercept of individual j at Time 0 (i.e., the overall or average level of alcohol use across 3 time points), β_{1j} is the rate of linear change in alcohol use for individual j over time (i.e., slope), and r_{ij} is the residual variance in repeated measures for individual j, which is assumed to be independent and normally distributed.
In order to ascertain whether a linear model is the best fit for the data, I compared the linear model to a mean-and-variance model: Y_{ij} *(alcohol use)* $= \beta_{0j} + r_{ij}$. Given that the mean-and-variance model is nested in the linear model, the relative fit of each model can be compared by subtracting the deviance statistics of the nested model (the mean-and-variance model) from the larger model (the linear model). I predicted that the deviance statistics for the two models will be significantly different, therefore suggesting that the model with fewer parameter constraints (i.e., the linear model) is a better fit for the data. The same procedure was used to address the exploratory aim of whether decision making is stable over time over time, and will be repeated for each of the three decision making tasks (i.e., IGT, Cups Task, and DDT). I hypothesized that there will not be systematic linear change in decision making over the first year of college.

I next tested the hypothesis that poorer decision making at Time 1 will be associated with greater escalation in alcohol use over the first year of college. Within the Level 1 linear equation (Y_{ij} *(alcohol use)* $= \beta_{0j} + \beta_{1j}$ *(Time)*$+ r_{ij}$), each parameter includes a constant and a unique error term such that each Level 1 coefficient is modeled as a function of the group mean (e.g., γ_{00}) and error (e.g., μ_{0j}). Each measure of decision making (i.e., IGT, Cups Task, DDT) will be entered separately as grand-centered into the Level 2 equation for both intercept and time parameters such that β_{0j} (intercept) $= \gamma_{00} + \gamma_{01}$ (decision making at Time 1) $+ \mu_{0j}$ and β_{1j} *(Time)* $= \gamma_{10} + \gamma_{11}$ (decision making at Time 1) $+ \mu_{1j}$. In GCM, the coefficients can be understood as functionally similar to unstandardized regression coefficients, and they represent the degree of association between two variables. These analyses were repeated to determine whether decision making at time 1 predicts drinking at the end of the first year of college (i.e., time 3).
To allow for the possibility that decision making may not be a risk factor, but rather a consequence of heavy drinking, I tested the hypothesis that drinking at time 1 predicts

average decision making abilities, and compared effect sizes. I did not expect this relationship to be significant.

Aim 2: To explore moderators of the relationship between decision making and drinking

As previously hypothesized, I expected that decision-making at Time 1 would be associated with greater escalation in drinking; however, I expected that the degree of association would vary as a function of moderating variables. To test the moderating effect of several established risk factors for increased drinking during the first year of college, the following equations were used:

Level 1: Y_{ij} *(alcohol use for a given individual)* $= \beta_{0j} + \beta_{1j}$ *(Time)* $+ r_{ij}$

Level 2: β_{0j} (overall (level of drinking) $= \gamma_{00} + \gamma_{01}$ (decision making at Time 1) + γ_{02} (moderator) + γ_{03} (decision-making x moderator) + μ_{0j}

β_{1j} *(TIME:* linear change in drinking*)* $= \gamma_{10} + \gamma_{11}$ (decision making at Time 1) + γ_{12} (moderator) + γ_{13} (decision-making x moderator) + μ_{1j}

I predicted that the interaction terms (γ_{03} and γ_{13}) would be significant, which would suggest significant moderation. Specifically, I expected that poorer decision making at Time 1 would be more strongly associated with escalation in alcohol use if participants: are male, have a family history of alcohol abuse, report a longer history of pre-college alcohol use, hold more positive alcohol expectancies, and are more impulsive.

Aim 3: To assess whether drinking and negative consequences covary over the first year of college.

I tested the baseline model for negative consequences as described in Aim 1. I expected that there will be significant systematic escalation in negative consequences over the first year of college; I also expected that there would be significant between-subject variability in rates of change of negative consequences. I predicted that rates of change in drinking would be significantly associated with rates of change in negative consequences over the first year of college. To the extent that there is greater positive linear change in drinking over time, I predicted that negative consequences would increase at a steeper rate.

Aim 4: To establish ecological validity of decision making tasks in a sample of first-year college students

This aim was examined in the present study by computing correlational analyses between negative consequences of drinking and scores on the IGT, Cups Task, and DDT. Hierarchical regression analysis will be used to determine if the number of drinking consequences predicts performance on these tasks. Significant results will be taken as evidence that laboratory measures of decision making are associated with real-life problems associated with heavy drinking.

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APPENDIX

TABLES

Table A1

Descriptive Statistics at Time 1 (N = 136)

Participant Characteristics	M	*SD*
Pre-college alcohol use		
Avg number drinks on an occasion senior yr high school	3.31	2.41
Avg number drinks on an occasion junior yr high school	1.68	2.31
Avg number drinks on an occasion sophomore yr high school	1.06	2.08
Avg number drinks on an occasion freshmen yr high school	.36	.95
Age of "regular drinking"	17.07	.99

Participant Characteristics	%
Pre-college negative consequences of alcohol use	
Had a hangover	71.0%
Got behind in school work	8.0%
Did something you later regretted	44.2%
Forgot where you were or what you did	36.2%
Argued with friends	34.1%
Unplanned sexual activity	34.1%
Did not use protection when you had sex	20.3%
Damaged property	7.2%
Trouble with campus or local police	7.2%
Got hurt or injured	12.3%
Required medical treatment for alcohol overdose	0.7%
Past 30-day negative consequences of alcohol use	
Had a hangover	55.1%
Got behind in school work	11.6%
Did something you later regretted	18.8%
Forgot where you were or what you did	18.1%
Argued with friends	13.0%
Unplanned sexual activity	13.8%
Did not use protection when you had sex	2.93%
Damaged property	0.7%
Trouble with campus or local police	.6%
Got hurt or injured	5.8%
Required medical treatment for alcohol overdose	0.0%
Past 30-day binge drinking (total)	52.2%
Men	72.0%
Women	47.8%
Past 30-day frequent binge drinking	23.9%
Men	36.0%
Women	21.2%

Table A2

Descriptive Statistics at Time 2 (N = 134)

Participant Characteristics	%
Past 30-day negative consequences of alcohol use	
Had a hangover	54.5%
Got behind in school work	14.4%
Did something you later regretted	23.9%
Forgot where you were or what you did	26.1%
Argued with friends	17.2%
Unplanned sexual activity	6.0%
Did not use protection when you had sex	3.7%
Damaged property	3.0%
Trouble with campus or local police	2.2%
Got hurt or injured	5.2%
Required medical treatment for alcohol overdose	0.0%
Past 30-day binge drinking (total)	52.2%
Men	79.2%
Women	46.4%
Past 30-day frequent binge drinking	26.9%
Men	50.0%
Women	21.8%

Table A3

Descriptive Statistics at Time 3 (N = 102)

Participant Characteristics	%
Past 30-day negative consequences of alcohol use	
Had a hangover	63.7%
Got behind in school work	23.5%
Did something you later regretted	25.5%
Forgot where you were or what you did	27.5%
Argued with friends	23.5%
Unplanned sexual activity	9.8%
Did not use protection when you had sex	5.9%
Damaged property	3.9%
Trouble with campus or local police	2.0%
Got hurt or injured	7.8%
Required medical treatment for alcohol overdose	1.0%
Past 30-day binge drinking (total)	61.4%
Men	72.2%
Women	59.0%
Past 30-day frequent binge drinking	26.5%
Men	38.9%
Women	23.8%

Table A4

Descriptive Statistics for Alcohol Use at Times 1 - 3

	Time 1		Time 2		Time 3	
Alcohol Use	M	*SD*	M	*SD*	M	SD
Harmful Drinking (AUDIT)	7.27	4.73	7.71	4.84	8.67	4.85
Drinking Quantity	4.26	2.85	4.20	2.55	4.47	2.50
Binge Frequency	3.50	3.90	3.54	3.56	3.57	3.23

Table A5

Descriptive Statistics for Negative Consequences of Alcohol Use

Variable (% endorsing)	Time 1	Time 2	Time 3
Had a hangover	55.1%	54.5%	63.7%
Got behind in school work	11.6%	14.9%	23.5%
Did something you later regretted	18.8%	23.9%	25.5%
Forgot where you were or what you did	18.1%	26.1%	27.5%
Argued with friends	13.0%	17.2%	23.5%
Unplanned sexual activity	13.8%	6.0%	9.8%
Did not use protection when you had sex	2.93%	3.7%	5.9%
Damaged property	0.7%	3.0%	3.9%
Trouble with campus or local police	3.6%	2.2%	2.0%
Got hurt or injured	5.8%	5.2%	7.8%
Required medical treatment for alcohol overdose	0.0%	0.0%	1.0%

Table A6

Means and Standard Deviations for Measures of Decision Making Times 1-3

Decision-Making Task	M	SD
1. T1 IGT	11.25	29.53
2. T1 DDT	0.14	0.62
3. T2 DDT	0.13	0.68
4. T3 DDT	0.23	1.03
5. T1 Total Risk – Gain	16.02	5.46
6. T2 Total Risk – Gain	15.31	5.71
7. T3 Total Risk – Gain	16.25	5.69
8. T1 Total Risk – Loss	17.74	6.28
9. T2 Total Risk – Loss	17.33	6.31
10. T3 Total Risk – Loss	16.52	6.31
11. T1 Gain Sensitivity	2.28	2.93
12. T2 Gain Sensitivity	2.81	3.21
13. T3 Gain Sensitivity	2.23	2.93
14. T1 Loss Sensitivity	1.61	3.00
15. T2 Loss Sensitivity	1.83	2.98
16. T3 Loss Sensitivity	1.97	3.05

Table A7

Correlations between indicators of alcohol use and measures of decision making

	Alcohol Use			Decision Making					
	Harm	Qty	Freq	IGT	DDT	Gain	Loss	Gain Sens	Loss Sens
Harmful Drinking	---								
Drinking Quantity	.68*	---							
Binge Frequency	.72*	.70*	---						
IGT	.03	.16	.04	---					
DDT	-.01	-.08	-.04	-.10	---				
Cups-Gain Risk Taking	.17	-.05	.07	-.10	.07	---			
Cups-Loss Risk Taking	.17	-.06	.13	-.19	.03	.62*	---		
Cups-Gain Sensitivity	-.07	.02	-.06	-.19	-.07	-.17*	-.05	---	
Cups-Loss Sensitivity	-.01	.02	.05	.06	-.13	-.14	-.00	-.22*	---

* $p < .01$

Table A8

Associations between Harmful Drinking (AUDIT Scores) and Decision Making Tasks Over The First Year of College

	Decision Making → AUDIT				AUDIT → Decision Making				Effect Size Comparison
	Coefficient	SE	*t*(134)	Eff. size *r*	Coefficient	SE	*t*(134)	Eff. size *r*	χ^2 (1)
IGT									
Overall Levels	.01	0.01	1.08	.09	*na*[a]	*na*[a]	*na*[a]	*na*[a]	*na*[a]
Changes	.00	.00	.66	.06	*na*[a]	*na*[a]	*na*[a]	*na*[a]	*na*[c]
DDT									
Overall Levels	-0.12	.35	-.36	.03	.01	.01	.85	.07	-0.33
Changes	-.07	.08	-.82	.07	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Total Risk Gain									
Overall Levels	.13	.06	2.08**	.18	.13	.08	1.77	.15	.27
Changes	-0.04	.03	-1.35	.12	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Total Risk Loss									
Overall Levels	.09	.06	1.36	.12	.09	.09	.97	.08	.34
Changes	-.03	.03	-1.12	.10	-0.10	.08	-1.21	.10	0.0
Cups – Gain Sensitivity									
Overall Levels	.05	.14	.34	.03	-0.02	.04	-0.38	.03	0.0
Changes	.17	.05	3.20*	.27	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Loss Sensitivity									
Overall Levels	.01	.12	.05	.00	.02	.04	.63	.05	-0.41
Changes	.02	.05	.46	.04	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]

Note. Comparisons of the effects of under- vs. overprovision were conducted using chi-square tests to compare unstandardized regression coefficients. Effect size *r* _ √[*t*2/(*t*2 _ *df*)].

* *p* < .01, ** *p* < .05.

Table A8—continued

[a]The IGT was only administered at Time 1. [b]A mean-and-variance model was specified for this variable.[c]Both variables did not have slope coefficients.

Table A9

Associations between Drinking Quantity and Decision Making Tasks Over The First Year of College

	Decision Making → Quantity				Quantity → Decision Making				Comparison
	Coefficient	SE	*t*(134)	Eff. size *r*	Coefficient	SE	*t*(134)	Eff. size *r*	χ^2 (1)
IGT									
Overall Levels	.02	.01	2.65*	.22	*na*[a]	*na*[a]	*na*[a]	*na*[a]	*na*[a]
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[a]	*na*[a]	*na*[a]	*na*[a]	*na*[a]
DDT									
Overall Levels	-0.14	.12	-1.22	.10	-0.01	.02	-0.43	.04	.51
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Total Risk Gain									
Overall Levels	-0.01	.04	-0.37	.03	-0.16	.14	-1.19	.10	-0.59
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Total Risk Loss									
Overall Levels	.01	.04	.36	.03	.07	.16	-0.43	.04	-0.08
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	-0.21	.13	-1.61	.01	*na*[c]
Cups – Gain Sensitivity									
Overall Levels	.05	.07	.73	.06	.06	.07	.88	.08	-0.17
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Loss Sensitivity									
Overall Levels	0.01	.06	.19	.02	.12	.07	1.68	.14	-1.02
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]

Note. Comparisons of the effects of under- vs. overprovision were conducted using chi-square tests to compare unstandardized regression coefficients. Effect size *r* _ √[*t*2/(*t*2 _ *df*)].

* $p < .01$

Table A9—continued

[a]The IGT was only administered at Time 1. [b]A mean-and-variance model was specified for this variable.[c]Both variables did not have slope coefficients.

Table A10

Associations between Binge Drinking Frequency and Decision Making Tasks Over The First Year of College

	Decision Making → Binge Frequency				Binge Frequency → Decision Making				Comparison
	Coefficient	SE	*t*(134)	Eff. size *r*	Coefficient	SE	*t*(134)	Eff. size *r*	χ^2 (1)
IGT									
Overall Levels	.01	.01	1.16	.01	*na*[a]	*na*[a]	*na*[a]	*na*[a]	*na*[a]
Changes	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[a]	*na*[a]	*na*[a]	*na*[a]	*na*[a]
DDT									
Overall Levels	-0.21	.21	-0.98	.08	.002	.02	.10	.01	.58
Changes	.01	.26	.03	.00	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Total Risk Gain									
Overall Levels	.02	.05	.48	.04	.002	.08	.03	.00	.33
Changes	-0.03	.03	-0.99	.08	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Total Risk Loss									
Overall Levels	-0.06	.04	1.44	.12	.10	.10	1.00	.09	.26
Changes	-0.03	.03	-0.99	.08	-0.10	.11	-0.91	.08	0.0
Cups – Gain Sensitivity									
Overall Levels	.04	.10	.44	.04	.005	.05	.093	.01	.25
Changes	.11	.04	2.68*	.23	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]
Cups – Loss Sensitivity									
Overall Levels	.03	.08	.41	.04	.07	.04	1.63	.14	-0.86
Changes	-0.02	.04	-0.50	.04	*na*[b]	*na*[b]	*na*[b]	*na*[b]	*na*[c]

Note. Comparisons of the effects of under- vs. overprovision were conducted using chi-square tests to compare unstandardized regression coefficients. Effect size *r* _ √[*t*2/(*t*2 _ *df*)].

* $p < .01$

Table A10—continued

[a]The IGT was only administered at Time 1. [b]A mean-and-variance model was specified for this variable.[c]Both variables did not have slope coefficients.

Table A11

Correlations between Indicators of Alcohol Use and Composite of Negative Consequences of Drinking

	Negative Consequences		
	Time 1	Time 2	Time 3
Alcohol-Use (Time 1-3)			
1. T1 Harmful Drinking	.37***	.26**	.16
2. T2 Harmful Drinking	.33***	.38***	.15
3. T3 Harmful Drinking	.27**	.23*	.33**
4. T1 Drinking Qty	.31***	.23**	.02
5. T2 Drinking Qty	.29**	.25**	.04
6. T3 Drinking Qty	.24*	.07	.09
7. T1 Binge Freq	.38***	.11	.12
8. T2 Binge Freq	.29**	.40***	.22*
9. T3 Binge Freq	.15	.16	.25

Note. Time 1 *N* = 137; Time 2 *N* = 133; Time 3 *N* = 102. All correlations are *NS.*

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table A12

Covariation between indicators of alcohol use and alcohol-related negative consequences

Drinking Variable	Coefficient	SE	*t*(135)	Eff. size *r*
Harmful Drinking (AUDIT)	0.07	0.01	4.89	.39
Past 30 Day Drinking Qty	0.10	0.03	3.80	.31
Past 30 Day Binge Freq	0.12	0.02	5.13	.40

Table A13

Correlations between Measures of Decision Making at Time 1 and Composite of Negative Consequences of Drinking at Times 1-3

	Negative Consequences		
	Time 1	Time 2	Time 3
Decision-Making Task			
1. IGT	-.02	.08	-.03
2. DDT	-.01	.12	.03
3. Total Risk-Gain	.08	-.01	.08
4. Total Risk-Loss	.02	-.01	.06
5. Gain Sensitivity	-.11	-.14	-.05
6. Loss Sensitivity	-.13	.08	.07

Note. Time 1 N = 137; Time 2 N = 133; Time 3 N = 102. All correlations are *NS*.