2009

Cognitive modeling analysis of decision-making processes in young adults at-risk and not at-risk for alcohol dependence

Lori Anne Wagner

COGNITIVE MODELING ANALYSIS OF DECISION-MAKING PROCESSES IN YOUNG ADULTS AT-RISK AND NOT AT-RISK FOR ALCOHOL DEPENDENCE

BY

LORI ANNE WAGNER

BS, Binghamton University, State University of New York, 2004

THESIS

Submitted in partial fulfillment of the requirements for
the degree of Master of Science in Psychology
in the Graduate School of
Binghamton University
State University of New York
2009

Accepted in partial fulfillment of the requirements for
the degree of Master of Science in Psychology
in the Graduate School of
Binghamton University
State University of New York
2009

Peter J. Donovick, Ph.D ___________________________________ December 15, 2008
Department of Psychology, Binghamton University

Matthew D. Johnson, Ph.D ___________________________________ December 15, 2008
Department of Psychology, Binghamton University

Kenneth J. Kurtz, Ph.D ___________________________________ December 15, 2008
Department of Psychology, Binghamton University

Abstract

This study used the Valence-Expectancy Learning model, a mathematical cognitive model, to dissect young adult performance on the Iowa Gambling Task (IGT). Drinking behavior and monetary incentive were examined as predictors of performance on the IGT. No differences were found among groups when data were analyzed using traditional behavioral analyses. However, when the Expectancy-Valence Learning model was applied to the data, differences between groups were found related to attention and choice consistency. Importantly, the cognitive model was not a good fit for fifty-seven percent of the data, meaning that it did not succeed in explaining how the participants' choices were dependent on trial-by-trial feedback. This may indicate that many young adults in this study were not invested in the task.

Dedication

For Augustine, who was an inspiration in life, and who continues to inspire from above.

Acknowledgements

Many individuals aided in the completion of this study and I am grateful for the help I have received. I would like to thank my advisor Dr. Peter J. Donovick for his continued guidance and support. Thank you for the contributions of my committee members Drs. Kenneth Kurtz and Matthew Johnson in review of the project and advice on its final form. Thank you to the members of the Environmental Neuropsychology Laboratory for being supportive of me throughout this process and for being great friends. I'd especially like to thank Dr. Emily Anderson-Mackillop whose research inspired me and whose guidance and suggestions were invaluable throughout this project. I'd also like to thank Bethany Williams for her assistance over the course of this study. Lastly, thank you to my family and friends for seeing me through this, especially Billy, who has sacrificed a lot to help me get here.

Table of Contents

List of Tables

List of Figures

Cognitive modeling analysis of decision-making processes in young adults at-risk and not at-risk for alcohol dependence

Human adolescence is a transitional period between youth and adulthood in which many developmental changes take place. Spear (2000) suggests that developmental events in the brain encourage many of the behavioral strategies seen in adolescence, including increased risk-taking and novelty-seeking. Indeed, substantial evidence indicates that the brain continues to develop throughout adolescence into early adulthood, particularly in regions thought to be responsible for decision-making (Giedd et al., 1996; Mukherjee, et al., 2002; Sowell, Thompson, Holmes, Jernigan, & Toga, 1999; Sowell, Thompson, Tessner, & Toga, 2001). Studies have pointed to the prefrontal cortex (PFC) as being a key component of decision-making (Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Damasio, & Damasio, 2000; Bechara, Damasio, Tranel, & Anderson, 1998; Bechara, et al., 2001; Blair, Colledge, & Mitchell, 2001; Bunge, et al., 2002; Hooper, Luciana, Conklin, & Yarger, 2004; Elliot, Dolan, & Frith, 2000). Developmental and functional neuroimaging research supports continued prefrontal development during adolescence (Hooper, et al., 2004). Therefore, it is possible that the increased risk-taking seen in adolescence compared to older adults is due to a relatively underdeveloped PFC.

The pattern of decision making seen in adolescence leads to high levels of morbidity and mortality (Eaton et al., 2006, Steinberg, 2004). More than fifty-percent of adolescents engage in drunk driving, the use of illegal drugs, sex without contraception or protection, and minor criminal activities (Maggs, Almeida, & Galambos, 1995). Some researchers suggest that increased levels of novelty-seeking during this time period may be evolutionarily adaptive because it promotes learning (Ernst & Paulus, 2005). However, there are high societal costs of dangerous adolescent activities, including disease, injury, human suffering, and associated economic costs (Reyna & Farley, 2006, Steinberg, 2007). Therefore, a better understanding of the components of decision-making during adolescence could help in formulating better tactics for reducing dangerous risk-taking behaviors.

Decision-making is broadly defined as the process of forming preferences, selecting and executing actions, and evaluating outcomes (Ernst & Paulus, 2005). Ernst and Paulus (2005) break down decision-making into a series of steps that follow an input-process-output-feedback structure. According to these researchers; "*Input* refers to the presentation of stimuli, each predicting a measurable rewarding or aversive outcome; *process* refers to the appraisal of these stimuli and formation of preference; *output* refers to the action carried out in response to the selected stimulus. *Feedback* is the experience and evaluation of the outcome that follows that action perpetuated on the selected stimulus" (p. 597). Evaluating these individual steps in the decision-making process may help isolate which aspect of decision-making is affected in various disorders (Ernst & Paulus, 2005).

One such population in which this input-process-output-feedback analysis has been helpful is with patients who are substance-dependent. These individuals generally display decision-making patterns that are different from those of their non-substance-dependent counterparts. For one, substance-dependent individuals tend to display a hypersensitivity to reward, choosing high immediate gains despite higher future losses (Bechara & Damasio, 2002a). Secondly, substance-dependent individuals tend to inaccurately evaluate the probability and magnitude of positive or negative potential outcomes (Rogers and Robins, 2001). Also, substance-dependent individuals are more likely to select relatively riskier options than non-substance-dependent individuals (Petry et al., 1998). Lastly, substance-dependant individuals display a steeper weakening of consequence effects due to delay (temporal discounting function) than non-substance-dependent individuals (Petry et al., 1998). Ernst and Paulus (2005) posit that increased activation of the prefrontal cortex in substance-dependent subjects in response to cues that elicit craving responses could reflect an increased valuation of the drug-related stimuli relative to non-substance-dependent individuals. This would therefore affect the *process* stage of the decision-making process.

Decision-making deficits have been documented in other populations, such as individuals with prefrontal cortex damage (Bechara, Tranel, & Damasio, 2000). These individuals have difficulty controlling their impulses which leads to negative consequences in everyday life. Young adults also appear to have deficits in decision-making which lead to problems in their daily lives (Steinberg, 2008). Their difficulty appears to be related to increased risk-taking and lack of regard for future consequences (Steinberg, 2004). Studies providing behavioral data on decision-making have been done to support theoretical accounts such as Ernst and Paulus' (2005). A widely used behavioral task to measure decision-making is the Iowa Gambling Task.

Iowa Gambling Task Development and Research

Bechara, Damasio, Damasio, and Anderson (1994) developed a simulated gambling task (IGT) to examine sensitivity to reward and punishment contingencies in patients with prefrontal cortex damage. In this task, participants make selections from four decks of cards with variable monetary reward and punishment. Some studies using the IGT use real money while others use hypothetical money. Participants are instructed to maximize their winnings but are not given any information about the reward/punishment schedule associated with each deck. Because they are not given any information about the reinforcement schedule, the participants must sample cards from each of the decks and make associations between the decks and their particular rewards and punishments in order to maximize their winnings. Those who perform well on the IGT make proportionally more advantageous selections which indicates superior decision-making. Research from Bechara and colleagues has shown that patients with ventromedial prefrontal cortex (vmPFC) damage perform worse on the IGT than comparison subjects (Bechara et al., 1994; Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, & Damasio, 2000b; Bechara, Tranel, Damasio, & Damasio, 1996). The patients with vmPFC damage continue to make disadvantageous choices even after many trials, while comparison subjects learn to avoid the disadvantageous decks over time. This decision-making deficit has been seen in other populations, including substance-dependent subjects and adolescents, who perform similarly to patients with vmPFC damage (for a review, see Bechara & Damasio, 2002a; Anderson, 2006). Researchers hypothesize that the decision-making deficits seen in substance-dependent individuals and adolescents on the IGT may reflect a dysfunction or underdevelopment of the prefrontal cortex (Bechara & Damasio, 2002a; Grant, Contoreggi, & London, 2000; Anderson, 2006). Unfortunately the traditional method used for analyzing data from the IGT (analyzing advantageous choices over time) does not allow one to identify specific psychological processes involved. This led to the creation of the Expectancy-Valence Learning Model discussed below.

Cognitive Modeling Research

The creators of the IGT state that the task "simulates real-life decisions in the way it factors reward, punishment, and uncertainty of outcomes" (Bechara & Damasio, 2002, p. 1675), implying that the skills required to perform well on the IGT are similar to those necessary for effective real-life decision making. However, because the IGT was designed to investigate the complex interaction of cognitive and motivational processes, it is hard to discern what specific psychological factors are responsible for the decision-making deficits seen on this task (Busemeyer & Stout, 2002). This observation led to the genesis of the Expectancy-Valence Learning Model designed to isolate the psychological processes involved in decision-making on the IGT (Busemeyer & Stout, 2002). In the Expectancy-Valence Learning Model, the gains and losses experienced on each trial are combined into a single affective reaction termed the "valence". The decision maker learns expectancies about the valence produced by each deck by an adaptive learning mechanism. These expectancies then function as inputs into a probabilistic choice mechanism that determines the deck selection on each trial. Busemeyer and Stout (2002) assert that this decision-making process can be broken down into three different psychological components. These components examine: (1) the influence of rewards and punishments on the evaluation of options (the attention parameter); (2) the rate at which contingency payoffs are learned (the learning-rate parameter), and; (3) the consistency between learning and responding (the response-sensitivity parameter). Each of these parameters will be discussed in detail below.

The following descriptions of the parameters were obtained from Yechiam, Busemeyer, Stout, & Bechara (2005).

Attention Parameter (attentions to losses versus wins)

The Attention parameter represents attention to gains and losses. A deck is selected on each trial and the payoffs (gains and possible losses) are awarded. The model assumes that the participant differentially weighs the gains and losses experienced. The valence of payoffs experienced is a weighted average of gains and losses:

$$v(t) = W \cdot win(t) - (1-W) \cdot loss(t)$$

where $v(t)$ is the valence on trial t, $win(t)$ is the amount of money won on trial t, $loss(t)$ is the amount of money lost on trial t, and W is a parameter that indicates the weight given to gains versus losses. W (the attention parameter) ranges from 0 to 1. Large values of W denote increasing attention to gains while small values denote attention to losses.

Learning-Rate Parameter (updating expectations)

The Learning-Rate parameter represents attention to most recent outcomes versus past outcomes. It is assumed that participants form expectancies about the anticipated consequences of choosing a card from each deck. The expectancy for each deck is updated as a function of both its previous value (which represents past experience) and the newly experienced payoffs on the current trial:

$$Ej(t) = Ej(t-1) + \Phi \cdot [v(t) - Ej(t-1)]$$

where $Ej(t)$ is the expectancy for deck j on trial t, Φ is the learning-rate parameter, and $[v(t) - Ej(t-1)]$ is an adjustment resulting from the prediction error (Busemeyer & Myung, 1992). Φ (the learning-rate parameter) ranges from 0 to 1 and controls the amount of adjustment from the prediction error. According to this model, "learning-rate" is defined as the rate at which contingency payoffs are learned. Large values of Φ cause rapid adjustments and denote strong recency effects and rapid discounting of past outcomes. Small values denote less discounting of past outcomes.

The Response-Sensitivity Parameter (choice consistency)

The Response-Sensitivity parameter represents the degree to which the participant applies the expectancies produced by the decks when selecting cards. It is assumed that consistency increases with experience. The probability of choosing a deck is determined by comparing the expectancy for that deck with the expectancies for the other decks:

$$Pr[Gj(t+1)] = \frac{e^{\theta(t) \cdot Ej(t)}}{\sum_k e^{\theta(t) \cdot Ek(t)}}$$

where $Pr[Gj(t)]$ is the probability that the individual will select deck j on trial t. $\theta(t)$ indicates the consistency between choices and the expectancies and is assumed to increase with experience. A power function for the sensitivity change over trials is used to calculate the probability that the individual will select a particular deck:

$$\theta(t) = (t/10)^c$$

where *c* is the response-sensitivity parameter. *c* ranges from –5 to 5. As *c* increases in magnitude, the choices become more dependent on the expectancies (so the deck with maximum expectancy is chosen). As *c* decreases in magnitude, choices become more random, inconsistent, and independent of the expectancies over time.

To summarize, the Expectancy-Valence Learning Model has three parameters: (1) attention (*W*), defined as attention given to losses as opposed to gains, (2) learning-rate (Φ), defined as attention given to most recent outcomes as opposed to past outcomes, and; (3) response sensitivity (*c*), defined as choice consistency.

The following is a description of the procedures used by Busemeyer and colleagues (Busemeyer & Stout, 2002; Yechiam et al., 2005) to analyze the Expectancy-Valence model. Similar procedures will be used for data analysis in the current study (see Data Analysis section).

Baseline Model

A baseline model is used as a standard for comparison against the Expectancy-Valence Learning Model. This model is a statistical model rather than a cognitive model, but like the Expectancy-Valence Learning Model, has three parameters that are estimated from the individual participants' data. However, unlike the cognitive model, the baseline model assumes that the choices are independently and identically distributed across trials. Busemeyer and Stout (2002) assert that this model is a strong competitor and that the Expectancy-Valence Learning Model "can perform better than this baseline model only if it succeeds in explaining how the choices depend on the sequence of trial-by-trial feedback" (p. 257).

Model Comparison Analyses

Maximum Likelihood Estimation

Parameters from the Expectancy-Valence Learning Model and baseline model are estimated separately for each participant using maximum likelihood methods. The parameters are optimized in order to maximize the likelihood of the observed sequence of 100 choices produced by each participant (Yechiam et al., 2005). For the Expectancy-Valence Learning Model, Busemeyer and Stout (2002) used the Nelder-Meade simplex algorithm (MathWorks Inc., 2000) as a nonlinear parameter search program to maximize the parameters. For the baseline model, the sample proportion of card choices from each deck for each participant is equal to the maximum likelihood estimates (Busemeyer et al., 2002).

Model Comparisons Using the G^2 Criterion

After the parameters that maximize the likelihood for each person for each model are determined, these parameters are used to compare the two models. Busemeyer and Stout (2002) use the G^2 statistic as a descriptive index of model performance. G^2 is a model-fit statistic with a similar distribution to the chi-square and uses a chi-square table for significance testing (Yechiam et al., 2005). Positive G^2 values indicate that the Expectancy-Valence Learning model performs better than the baseline model. The G^2 statistic is determined by calculating the difference in log likelihoods:

$$G^2 = 2(L_{Expectancy\text{-}Valence\ Learning\ model} - L_{baseline\ model})$$

Analysis of Parameter Estimates

In addition to analyzing the fit of the Expectancy-Valence Learning Model, it is necessary to analyze and interpret the individual model parameters (attention, learning-rate, and response sensitivity). According to the model, differences among groups on the attention parameter (*W*) would suggest that the performance deficits on the IGT result from the motivational system rather than the cognitive system (Busemeyer & Stout, 2002). Differences among groups on the learning-rate parameter (Φ) would suggest that performance deficits on the IGT result from the cognitive system rather than the motivational system (Busemeyer & Stout, 2002). Lastly, differences in the sensitivity parameter (*c*) would suggest that response mechanisms (impulsiveness, recklessness) account for the performance deficit rather than either cognitive or motivational systems (Busemeyer & Stout, 2002).

Means, medians, and standard deviations are calculated for each parameter and are used to determine whether each parameter differs significantly between groups. Additionally, confidence interval estimates, T-tests, and/or analyses of variance are calculated separately for each parameter to more rigorously assess observed differences.

The authors of the Expectancy Valence Learning model have reported poor performance on the IGT in numerous sub-populations. Decision-making deficits on the IGT have been observed in patients diagnosed with Huntington's disease (Stout, Rodawalt, & Siemers, 2001), obsessive-compulsive disorder (Cavedini et al., 2002), Asperger's syndrome (Johnson, Yechiam, Murphy, Stout, & Busemeyer, 2004, as cited in Yechiam et al., 2005), and chronic drug abuse (Bechara et al., 2001; Stout, Busemeyer, Lin, Grant, & Bonson, 2004; Yechiam, et al., 2004, as cited in Yechiam, et al., 2005). Also, patients with lesions in either the ventromedial prefrontal cortex (Bechara, et al., 1994; Damasio, 1994; Bechara & Damasio, 2002) or somatosensory and insular cortex (Bechara, Tranel, & Hindes, 1999) perform poorly on the IGT. While these results are usually interpreted as indications that all of these disorders share a common decision-making deficit, Yechiam and colleagues assert that it is possible that different psychological processes lead to poor IGT performance (Yechiam, et al., 2005).

In order to investigate the possibility that different decision-making deficits lead to poor performance on IGT, Yechiam and colleagues (2005) reviewed ten applications of the Expectancy-Valence Learning Model to IGT data. Their results are reproduced in Table 1 below. Note that the G^2 column shows the percentage of subjects in the sample and control groups whose combined deviation from the baseline model was greater than 0.

Table 1.
Percentage of Positive G^2 Values, Indicating an Improvement of the Adaptive Learning Model Over the Baseline Model, and Results of Significance Tests for the Parameters

Sample	Sample *n*	Control *n*	$G^2 > 0$ (sample + control)	Parameters significantly different between groups[a]
Asperger's syndrome	15	14	66%	attention (W^b), choice consistency (*c*)
RSIC lesion	22	12	62%	choice consistency (*c*)
Parkinson's disease	20	33	75% *	-
Young polydrug abusers	3	37	49%	-
Young alcohol abusers	27	32	67% *	-
VMPC lesion	21	12	76% *	learning-rate (Φ), choice consistency (*c*)
Normal seniors	63	87	61% *	attention (*W*), choice consistency (*c*)
Huntington's disease	14	33	75% *	-
Chronic cannabis users	25	16	24% *	learning rate (Φ), attention (*W*)
Chronic cocaine abusers	12	14	69% *	attention (*W*)

Note. RSC = right somatosensory and insular cortex; VMPC= ventromedial prefrontal cortex
[a]A significance level of $p < .05$ was adopted. [b]This parameter became significant after 150 trials.
*$p < .05$ in a binomial test.

All of the populations above except young polydrug abusers and young alcohol abusers showed differences from their control groups. It is possible that there were no differences found in the young polydrug and young alcohol abusers groups due to the low number of subjects. Also, the model fit as measured by the G^2 statistic was low, especially for the young polydrug abusers. Control groups for all of the populations were "matched on extraneous variables such as age, gender, and education" (Yechiam, et al., 2005, p. 975). It should be noted that the data for the control groups were obtained by

Yechiam and colleagues for comparison to the sample groups. Table 2 summarizes the significant differences found.

Table 2.
Significant Parameter Differences Between Neuropsychological Disorder Groups and Their Respective Controls

Sample	Significant parameter differences		
	More (+) or Less (-) Attention to Gains Over Losses (*W*)	Greater (+) or Lesser (-) Recency Effects (Φ)	More (+) or Less (-) Choice Consistency (*c*)
Asperger's syndrome	-	0	-
RSIC lesion	-	0	-
Parkinson's Disease	-	0	0
Young polydrug abusers	0	0	0
Young alcohol abusers	0	0	0
VMPC lesion	0	+	-
Normal seniors	+	0	+
Huntington's disease	0	0	0
Chronic cannabis users	+	+	0
Chronic cocaine abusers	+	0	0

Note: 0 indicates no significant difference between neuropsychological disorder group and control.

The results show that different psychological components are associated with poor performance on the IGT in different neuropsychological disorders (Yechiam, Busemeyer, Stout, & Bechara, 2005). These findings suggest that groups who perform poorly on the IGT may not do so for the same reasons. Thus, the Expectancy-Valence Learning Model is useful for isolating the particular decision-making deficits seen on this complex task.

Previous Research in the Environmental Neuropsychology Laboratory

In previous research completed in the Environmental Neuropsychology Laboratory, young adults at-risk for substance dependence and normal control peers were given the IGT as part of a larger study of decision-making in a college population

(Anderson, Castelda, MacKillop, Mattson, & Donovick, 2006). The at-risk group was operationally defined as having a score of 8 or above on the Alcohol Use Disorders Identification Test (AUDIT), a self-report measure that is commonly used in studies because of its ease of use and well-documented reliability and validity (Allen, Litten, Fertiz, & Babor, 1997; Fleming, Barry, & MacDonald, 1991; Hays, Merz, & Nicholas, 1995; Reinert & Allen, 2002). The researchers in the Environmental Neuropsychology Laboratory found that the young adults in both groups performed poorly on the IGT regardless of drinking behavior. Indeed, the participants in the Anderson et al. (2006) study were significantly below the previously reported net score cutoff for impaired decision-making (net score=10) established by Bechara and Damasio (2002a; 2002b). In fact, the performance of young adults on the IGT was similar to that of brain-damaged and substance dependent populations. These findings led to further research in the laboratory utilizing the IGT in a young adult population (17 to 20 year-old; Anderson, 2006). Anderson (2006) argued that neurodevelopmental changes occurring in young adulthood could account for poor IGT performance in young adults in her study. Her study examined the relationship between skin conductance, motivation, and decision-making in a young adult college population. While the group that was offered real money for their performance on the IGT ("motivation group") achieved relatively higher overall net scores than the groups that were not offered real money, the motivation group did not perform well on the task in an absolute sense, as they lost money overall. Additionally, even when combining real money and competition with other participants ("competition group"), the young adults in Anderson's (2006) study did not perform as well as healthy adults in previously published literature (Bechara & Damasio, 2002a).

These studies suggest that, in general, the young adult college population performs more poorly on the IGT than older adult populations. This performance deficit is exhibited regardless of risk-status for alcohol abuse or motivating factors. However, it is difficult to identify the specific cognitive, motivational, and response processes responsible for these observed behavioral deficits using traditional IGT analyses. The Valence-Expectancy Learning Model provides a theoretical basis for decomposing this complex task into separate processes. Thus, the current study used the Valence-Expectancy Learning Model to dissect young adult performance on the IGT in order to better understand the observed decision-making deficits.

Proposed Study

The purpose of the present study was to further examine IGT performance in a young adult college population. As done in previous studies in the Environmental Neuropsychology Laboratory, both monetary motivation and alcohol behavior were studied. However, because previous research in the Environmental Neuropsychology Laboratory showed that young adults perform poorly on the IGT regardless of risk-status for alcohol abuse or motivating factors, the Valence-Expectancy Learning Model was utilized to further analyze the decision-making of these individuals. Specifically, the Valence-Expectancy Learning Model was applied to identify differences in underlying psychological processes that might account for the performance of these individuals on the IGT.

The hypotheses of the current study were as follows:

Behavioral Hypotheses

1. There would be no differences between young adults who are not at-risk for alcohol dependence and those who are at-risk.
2. Young adults who are able to earn real money on the IGT would perform better than young adults who are not offered real money for their performance.
3. Males would perform better than females on the IGT, regardless of condition.

Cognitive Model Hypotheses

4. Young adults who are at-risk for alcohol dependence would differ from young adults who are not at-risk on the attention parameter. At-risk young adults would pay more attention to wins than losses than those who are not at-risk. They would not differ on memory or consistency parameters.
5. Young adults who have the opportunity to earn real money on the IGT would differ on the consistency parameter, making more choices from the deck with the maximum expectancy. They would not differ on the attention or memory parameters.

Method

Participants

The current study used data collected in the Environmental Neuropsychology Laboratory between April and November of 2005. In that study, 174 undergraduates enrolled at Binghamton University were recruited as participants. They were selected based on their alcohol-related behaviors as defined by their scores on the Alcohol Use Disorders Test (AUDIT) given during mass testing. They were assigned to either the Motivation (possible monetary compensation) or Control (no monetary compensation) group based on AUDIT score (At-Risk ≥8) and gender so that each group was approximately 50% male and 50% at-risk for alcohol abuse. There were 87 participants in each group (Motivation or Control). The participants received course credit for participation and those in the Motivation condition had the opportunity to earn monetary compensation. The mean age of the sample was 18.8 (*SD* = 0.94) years and the ethnicity of the participants was: 60% Caucasian, 27% Asian, 4% Hispanic/Latino, 8% Black/African American, 1% Pacific Islander, and 1% Other.

Materials

Iowa Gambling Task (IGT; A'B'C'D' version; Bechara, Tranel, & Damasio, 2000b)**:** Overall performance on the IGT was measured by a monetary amount displayed on the computer screen indicating total amount won or lost, but this amount did not translate into actual monetary gain. Therefore, the monetary gains and losses described below represent hypothetical money, except where noted. In the version used, the participant used a mouse to select one of four cards displayed on a computer screen. The decks were labeled: A, B, C, and D. Table 3 summarizes the contingencies associated with each of the four decks.

Table 3.
Differences between Decks in the IGT

	Disadvantageous Decks		Advantageous Decks	
	A	B	C	D
Reward for each selection	$100	$100	$50	$50
Magnitude of loss/10 cards	$1,250	$1,250	$250	$250
Frequency of loss/10 cards	5	1	5	1
Net gain or loss/10 cards	$-250	$-250	$250	$250
Classification	Disadvantageous, frequent punishment	Disadvantageous, infrequent punishment	Advantageous, frequent punishment	Advantageous, infrequent punishment

The participant earned a reward every time a card was drawn ($100 for Decks A and B; $50 for Decks C and D). Sometimes, a card also had a penalty (A and B had a total penalty of $1,250 for every ten cards; C and D had a total penalty of $250 for every ten cards). Therefore, choosing cards from the two disadvantageous decks (A and B) resulted in an overall net “loss” while choosing from the two advantageous decks (C and D) resulted in an overall net “gain”. Although on this version of the task it was possible to exhaust the decks, this did not happen in the current study.

As can be seen in Table 3, the distribution of the losses over trials distinguished Deck A from B and Deck C from D. Decks A and C had five smaller losses for every ten cards while decks B and D had one larger loss for every ten cards. Choosing from the advantageous decks resulted in lower immediate reward and lower overall punishment than choosing from the disadvantageous decks. In order to win money in the game the participant needed to make more choices from the advantageous decks than from the disadvantageous decks.

Every time the participant selected a card the computer played a sound signifying a win or loss and displayed a happy or sad face. In addition, a message was displayed indicating the amount of money won or lost. A green bar on the top of the screen indicated a $2000 credit to start the game. The red bar underneath it displayed how much hypothetical money the participant borrowed to play the game, and how much money they would theoretically have to pay back before calculating the total amount won or lost.

Alcohol Use Disorders Identification Test (AUDIT; Babor, Higgins-Biddle, Saunders, & Monteiro, 2001)**:** The AUDIT is a ten-item self-report screening measure that consists of questions regarding recent alcohol use, alcohol dependence symptoms, and alcohol-related problems (see Appendix A). Each response has a score ranging from 0 to 4, providing a total score between 0 and 40. The reliability and validity of the AUDIT have been established in numerous studies (Allen, Litten, Fertiz, & Babor, 1997; Fleming, Barry, & MacDonald, 1991; Hays, Merz, & Nicholas, 1995; Reinert & Allen, 2002). Hazardous and harmful alcohol use and possible alcohol dependence is indicated by a score of 8 or above on the AUDIT (Babor, Higgins-Biddle, Saunders, & Monteiro, 2001). This score reflects a higher risk of alcohol-related problems. The AUDIT has been used in many previous studies at Binghamton University (see Anderson, 2006; Anderson, et al., submitted; Mackillop, et al., 2007).

Procedure- 2005 Study

The current study analyzed data collected between April and November of 2005. The procedures employed in the 2005 data collection were in keeping with the previous protocol used in the Environmental Neuropsychology Laboratory.

The participants in this study were selected based on their scores on the *Alcohol Use Disorders Test* (AUDIT) given during mass testing. All participants were tested individually. A score of 8 or above was used to define the At-Risk for alcohol dependence group (At-Risk). The participants were assigned to either the Motivation or Control group based on: (1) AUDIT score (At-Risk ≥8) obtained during mass testing, and; (2) gender. This method was applied so that each group would be approximately 50% male and 50% at-risk for alcohol abuse. Because some of the questions on the AUDIT assess recent alcohol use, the questionnaire was re-administered at the time of participation in the study to assure that the participants' group status (At-Risk or Not At-risk) had not changed since mass testing. The participant was classified as At-Risk or Not At-Risk based on the AUDIT score obtained at the time of participation in cases where the AUDIT score had indeed changed. A total of 15 AUDIT scores changed between mass testing and time of participation. Of these, 14 (10 females, 4 males) scores changed from At-Risk to Not At-Risk while only 1 (male) score changed from Not At-Risk to At-Risk. Consequently, approximately 40% of the females and 47% of the males were ultimately classified as At-Risk.

The participants were asked to sit in front of the IGT computer after reading and signing the consent form. In order to collect data for a co-occurring study, electrodes were affixed to the participant's non-dominant hand before they began playing the task as a measure of skin conductance response (note: this portion of the data set was not analyzed in the current study as it represents a different domain of information than that of interest for the current research question). The participants were then read the standard instructions for the IGT (Appendix B). On average, the participants spent 20 minutes playing the game. After the IGT, the participants completed the AUDIT. Total administration time was approximately 25 minutes.

Motivation Condition

In the Motivation condition, participants were read the standard instructions for the IGT but were informed that they could win real money based on their performance. They were able to win the money shown on the screen divided by 1,000. For example, if they won 1,000 dollars in the game, they would be given $1 of real money. This monetary incentive was also used in Anderson's (2006) dissertation and is in keeping with a previously published study examining the effect of monetary incentives on performance on the IGT (Anderson, 2006; Bowman & Turnbull, 2003). The participants were also informed that they would not have to pay back the experimenter if they lost money in the game. Additionally, if they won over $1,500 in the game ($1.50 of real money), they would receive a $5 bonus. This bonus incentive was implemented to match the procedure used in the Anderson (2006) study. The participants were asked to paraphrase the instructions to indicate that they understood that they would win the amount of money displayed on the computer screen divided by 1,000 (see Appendix C).

Control Condition

The participants in the control condition were administered the IGT in the standard administration procedure. There was no monetary compensation in this condition (see Appendix B).

Data Collection- 2005 Study

Consent

Each participant signed a consent form prior to participating indicating that they voluntarily agreed to be in the study. This form additionally stated that they would not be penalized if they chose not to participate in the study (see Appendix D).

Confidentiality

Each participant folder contains only a file number. All identifying information was kept in a locked cabinet separate from the participant files.

Investigators

Three undergraduate research assistants assisted in data collection and data entry. As required by the HSRRB at Binghamton University, each of the research assistants as well as the principal investigator completed the online course in research ethics prior to contact with participants or data.

Procedure- Current Study

The current study analyzed the data collected in the 2005 study. This data set has not been previously analyzed. The principal investigator used both traditional behavioral data analyses and the Expectancy-Valence Learning Model to examine performance on the IGT (see Introduction and Results sections). To the principal investigator's knowledge, no published studies have investigated young adult performance on the IGT using the Expectancy-Valence Learning Model. The current study identified psychological components associated with poor performance on the IGT in this young adult population of college students.

Stallen (2006) created a Microsoft Excel® application of the Expectancy-Valence Learning model to efficiently analyze IGT results. The Stallen program uses the formulas described by Busemeyer and Stout (2002) in Excel® format to estimate the parameters of the model as well as make model comparisons. Stallen's (2006) Microsoft Excel® application of the Expectancy-Valence Learning Model was used to analyze the cognitive modeling data in the current study.

Results

Participant Characteristics

One hundred seventy four undergraduate students participated in this study. The participants were assigned to either the Motivation or Control group based on: (1) AUDIT score (At-Risk ≥8) obtained during mass testing, and; (2) gender. However, as described in the methods section, a second AUDIT was administered at the time of participation to assure that the participants' group status (At-Risk or not At-risk) had not changed. When there were in fact discrepancies in the AUDIT scores, the score obtained at the time of participation was used for classification purposes. Thus, approximately 40% of the females and 47% of the males were ultimately classified as At-Risk.

The Control and Motivation groups were each 48% male. The mean age of the sample was 18.8 (*SD* = 0.94) years and the ethnicity of the participants was: 60% Caucasian, 27% Asian, 8% Black/African American, 4% Hispanic/Latino, 1% Pacific Islander, and 1% Other.

Table 4 indicates that the two groups tested in this study (Control and Motivation) were similar in terms of gender, age, and age range. In addition, there were no education or ethnicity differences between the two groups.

Table 4.

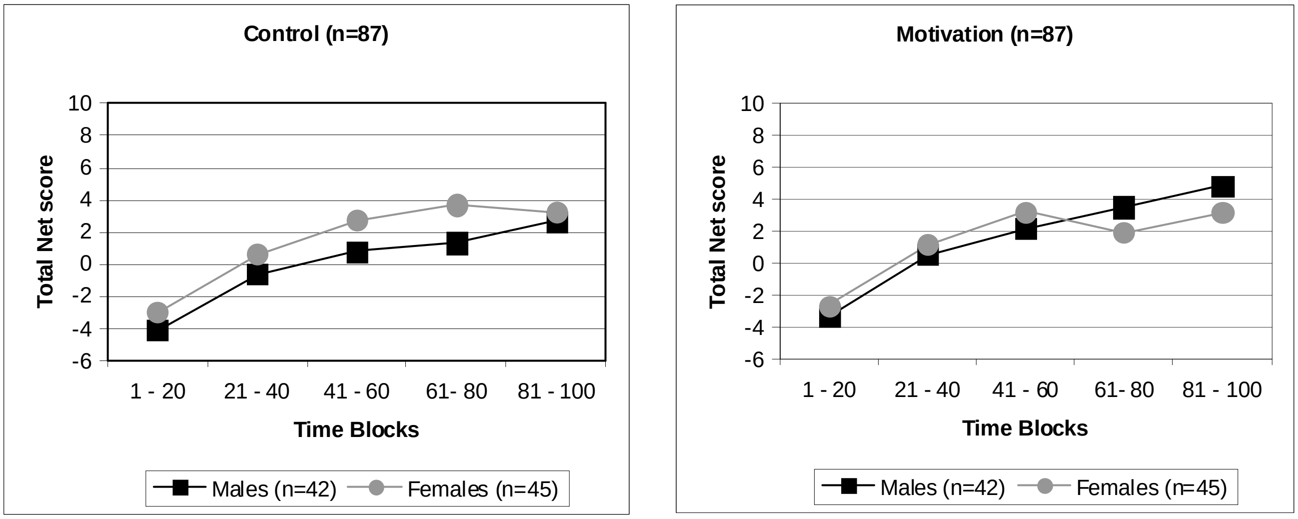
Demographic data of subjects participating in the IGT (N=174)

	Control (No Monetary Compensation)		**Motivation (Monetary Compensation)**	
	AUDIT < 8 *	**AUDIT ≥ 8 ***	**AUDIT < 8 ***	**AUDIT ≥ 8 ***
Total # of Subjects	54	33	48	39
Gender	26 ♂, 28 ♀	16 ♂, 17 ♀	20 ♂, 28 ♀	22 ♂, 17 ♀
Age (years; mean ± SD)	18.72 ± 0.81	19.00 ± 1.00	18.69 ± 0.93	18.95 ± 1.05
Age range (years)	18-21	18-21	18-21	18-22

* Note: AUDIT <8 = Not At-Risk for alcohol abuse; AUDIT ≥ 8 = At-Risk for alcohol abuse

As in previous IGT studies (Bechara & Damasio, 2002a; Bechara, Dolan, & Hindes, 2002b; Anderson, 2006), the 100 card selections were subdivided into blocks of 20 cards each. In each block, the number of selections from decks A and B (disadvantageous) were subtracted from the number of selections from decks C and D (advantageous) producing the net score for that block ((C + D) – (A + B)). Net scores above 0 indicate that participants were selecting advantageously while net scores below zero indicate that the participants were selecting disadvantageously. Figure 1 shows the net scores for males and females in the Control and Motivation conditions.

Figure 1. Control (n=87) and Motivation (n=87) condition net score over time blocks.



Although the current investigator had no a priori hypotheses about learning over time, the groups were compared for descriptive purposes. All groups chose more advantageously over time, but there were no significant differences among groups in the rate at which they learned. Anderson, Robeson, and Donovick (2005) found that young college students perform better on the IGT when given 150 trials compared to 100 trials in standard conditions. These findings suggest that young adults appear to make more advantageous decisions on the IGT when they are given more trials. Therefore, it is possible that learning rate differences would emerge in the current study if subjects were given more trials.

Behavioral Data Analyses

Data were analyzed with the Statistical Package for the Social Sciences for Windows, Version 15.0 (SPSS Inc., Chicago, IL). Data were examined for normality to ensure that the assumptions of parametric statistics were met before analyses were conducted.

A 2 (group) x 2 (AUDIT) x 2 (gender) univariate analysis of variance (ANOVA) was conducted to address the three behavioral hypotheses. An alpha level of .05 was used to determine whether findings were significant.

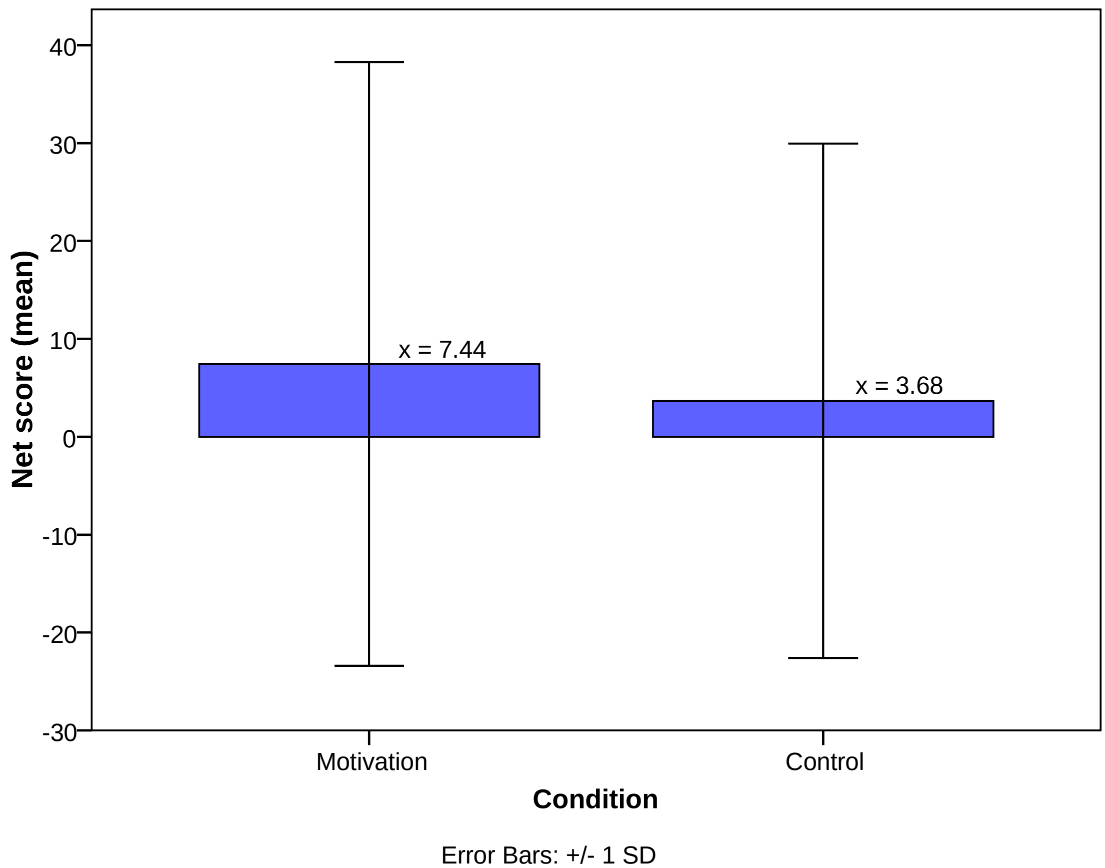
Recall that net score was calculated by subtracting disadvantageous deck selections from advantageous deck selections (net score= (C + D) – (A + B)). There were no net score differences among group, audit, or gender. Over half of the participants (101 participants; 58%) performed in the impaired range; that is, below the total net cutoff established in previous studies for impaired decision-making (net score= 10; Bechara & Damasio, 2002a; Bechara, Dolan, & Hindes, 2002b). *Table 5* shows the mean net score and standard deviation for each group. It is probable that the large net score standard deviation contributed to the null findings. *Figure 2* shows the mean for each experimental group with the error bars representing one standard deviation above and below the mean.

Table 5.
Mean net score of participants (N=174)

	AUDIT < 8 *	**AUDIT ≥ 8 ***
Motivation (*n*= 87)		
Male	4.90 (± 35.15) *n*= 28	9.18 (± 25.37) *n*= 28
Female	9.93 (± 30.64) *n*= 28	4.06 (± 34.29) *n*= 28
Control (*n*= 87)		
Male	8.15 (± 20.05) *n*= 26	16.38 (± 21.49) *n*= 16
Female	-1.14 (± 29.79) *n*= 28	-7.18 (± 28.13) *n*= 17

* Note: AUDIT <8 = Not At-Risk for alcohol abuse; AUDIT ≥ 8 = At-Risk for alcohol abuse

Figure 2. Average net score of control and motivation conditions.



These results support the current study's hypothesis that there would be no differences between young adults who are not at-risk for alcohol dependence and those who are at-risk. However, the other two behavioral data hypotheses in this study (2:Young adults who were able to earn real money on the IGT would perform better than young adults who were not offered real money for their performance; and 3: Males would perform better than females on the IGT, regardless of condition) were not supported. These results are unexpected given that previous studies conducted in the Environmental

Neuropsychology Laboratory using similar (in terms of age, education, ethnicity, and gender) participants did indeed find gender and monetary effects (Anderson, 2006; Anderson et al., 2006).

Cognitive Modeling Analyses

Comparisons with Baseline Model

After the optimum parameter estimates were found, the G^2 statistic was computed using the following equation:

$$G^2 = 2(L_{\text{Expectancy-Valence Learning model}} - L_{\text{baseline model}})$$

A positive G^2 statistic indicated that the Expectancy-Valence Learning model outperformed the baseline model. The Expectancy-Valence Learning Model produced a positive G^2 for 43% (76) of the participants. The average G^2 improvement of the Expectancy-Valence Learning Model over the baseline model was 15.24. The negative G^2 for the remaining 57% of the participants indicates that the Expectancy-Valence Learning Model did not succeed in explaining how the participants' choices were dependent on trial-by-trial feedback. Thus, it was not appropriate to further analyze the data from these participants. Therefore, the remaining cognitive modeling analyses were conducted utilizing the data from the 76 participants with a positive G^2. This subset of participants was similar to the original 174 participants in terms of age, education, ethnicity, gender, group, and AUDIT risk status.

Interestingly, while there were no net score differences found among the groups (see Behavioral Data Analyses section), when net scores were compared for those with positive versus negative G^2, significant net score differences were found. Participants with a positive G^2 had higher net scores than participants with a negative G^2 [$t(172)= 2.179$, $p=.031$]. Indeed, participants with positive G^2 had a mean net score of 10.87 while those with a negative G^2 had a mean net score of 1.43. Using Bechara and Damasio's (2002a; 2002b) net score cutoff of 10 for impaired decision-making, these results suggest that participants with a negative G^2 displayed impaired decision-making on the Iowa Gambling Task while participants with a positive G^2 did not. A 2 (group) x 2 (AUDIT) x 2 (gender) univariate ANOVA was conducted on this subset of subjects with a positive G^2 but no significant differences emerged.

Analysis of Parameter Estimates

The three parameters of the Expectancy-Valence Learning Model are: attention (*W*), attention given to losses as opposed to gains; learning-rate (Φ), attention given to most recent outcomes as opposed to past outcomes, and; response sensitivity (*c*), sensitivity of the choice mechanisms to the expectancies.

According to the model, differences among groups in the attention parameter would indicate deficits on the Iowa Gambling Task result from the attentional system, whereas differences among groups in the learning rate parameter would indicate performance deficits result from the cognitive system. Differences among groups on the response sensitivity parameter would indicate that recklessness and/or impulsivity are responsible rather than attentional or cognitive mechanisms (Busemeyer & Stout, 2002).

Two 2 (group) x 2 (AUDIT) x 2 (gender) univariate analyses of variance (ANOVA) were conducted to address each of the two cognitive modeling hypotheses. An alpha level of .05 was used to determine whether findings were significant. The means, medians, and standard deviations for the parameter estimates are shown below (*Table 4*).

Table 6.
Expectancy-Valence Learning Model Parameter Estimates

	Attention (*W*) (0 to 1)			Learning Rate (Φ) (0 to 1)			Response Sensitivity (*c*) (-5 to +5)		
Group	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
Control (n= 37; No Money)	0.32	0.09	0.40	0.48	0.41	0.32	1.05	0.99	2.17
Motivation (n=39; Money)	0.21	0.38	0.34	0.32	0.36	0.25	1.96	1.42	2.14

A 2 (group) x 2 (AUDIT) x 2 (gender) univariate ANOVA was conducted to examine the differences between the groups on the attention (*W*) parameter. The attention (*W*) parameter was significantly higher for the Control group than the Motivation group [$F_{1, 68}$= 7.216, p= .009]. This indicates that the Motivation group paid more attention to losses than the Control group. However, there were no attention (*W*) parameter differences found between males and females [$F_{1, 68}$= 1.207, p= .276] or At-Risk and Not At-Risk [$F_{1, 68}$= 0.086, p= .771] groups. Therefore, the hypothesis that young adults who were at-risk for alcohol dependence would differ on the motivation parameter, paying more attention to wins than losses than those who were not at-risk, was not supported.

A 2 (group) x 2 (AUDIT) x 2 (gender) univariate ANOVA was conducted to examine the differences between the groups on the response sensitivity (*c*) parameter. The difference between the Control and Motivation groups approached significance [$F_{1, 68}$= 3.378, *p*= .069], indicating that the members of Motivation group made choices that were somewhat more sensitive to their expectancies about the decks. There were no response sensitivity (*c*) parameter differences found between males and females [$F_{1, 68}$= 0.467, *p*= .497] or At-Risk and Not At-Risk [$F_{1, 68}$= 0.028, *p*= .869] groups. The hypothesis that young adults who had the opportunity to earn real money on the IGT would differ on the consistency parameter, making more choices from the deck with the maximum expectancy was marginally supported.

Although there were no a priori hypotheses regarding the learning rate (Φ) parameter, it was analyzed for descriptive purposes. A 2 (group) x 2 (AUDIT) x 2 (gender) univariate ANOVA was conducted. There were no learning rate (Φ) parameter differences between Motivation and Control [$F_{1, 68}$= 0.785, *p*= .379], males and females [$F_{1, 68}$= 0.330, *p*= .567], or At-Risk and Not At-Risk [$F_{1, 68}$= 1.927, *p*= .170] groups.

Discussion

The present study used the Iowa Gambling Task (Bechara et al.,2000) to investigate decision making in young adults. Poor performance on the IGT has been associated with impaired decision making as a result of ventromedial prefrontal cortex damage (Bechara et al., 1994; Damasio, 1998), substance abuse (Petry, 2001; Bechara & Damasio, 2002a), and immaturity of the frontal lobes (Hooper et al., 2004). Traditional IGT analyses (examining net scores over blocks of time) do not allow the researcher to attribute poor performance to specific steps in the decision making process. Busemeyer and Stout's (2002) Expectancy-Valence Learning Model provides a theoretical basis for decomposing decision making on the IGT into distinct psychological processes. Thus, we are better able to understand the mechanisms of complex decision making. The current study was the first to use the Expectancy-Valence Learning Model to examine decision making on the IGT in a large sample of young adults. The participants in this study represent a group of students from a competitive public university. As noted by Anderson (2006), however, the participants' performance on the IGT suggests that knowledge did not necessarily translate into advantageous decision-making strategies. Nevertheless, it would be wise to recognize this potential limitation when interpreting the results of this study.

In this study, differences between groups were not found using traditional behavioral analyses. However, when the Expectancy-Valence Learning model was applied to the data, interesting group differences emerged.

Results of Behavioral Data Analyses

Based on previous findings in the Environmental Neuropsychology Laboratory, it was hypothesized that there would be no IGT performance differences between young adults who are not at risk for alcohol dependence and those who are at-risk. The results of the current study support this hypothesis. Many consider the alcohol-related behaviors measured on the *AUDIT* to indicate recklessness, impulsivity, and poor decision-making. The findings of the current study suggest that real-life risky alcohol use does not necessarily translate into poor decision-making on the IGT. This is in keeping with Anderson's (2006) proposition that either: (1) performance on the IGT may not depend on real-world behaviors such as gambling or alcohol use; or (2) the IGT measures a different construct than decision-making, gambling, and impulsivity in the younger population.

The hypothesis that young adults who were able to earn real money on the IGT would perform better than young adults who were not offered real money for their performance was not supported in this study. This result are unexpected given that previous studies conducted in the Environmental Neuropsychology Laboratory using similar (in terms of age, education, ethnicity, and gender) participants did indeed find gender and monetary effects (Anderson, 2006; Anderson et al., submitted). It is possible that the total amount of money offered was not enough to influence the performance of the young adults in this study. Yet, interesting cognitive modeling differences between the Control and Motivation groups emerged and will be discussed below (see Cognitive Modeling Analyses).

The hypothesis that males would perform better than females on the IGT, regardless of condition, was not supported. Recent studies have found that females perform significantly worse on the IGT than males (Hooper et al., 2004; Overman et al., 2004). Hooper (2004) suggested that females are more punishment aversive; that is, their IGT performance reflects a desire to avoid frequent punishment. However, this puts these females in a position to lose more money on the task because they choose from the deck with the most infrequent but highest magnitude of punishment. In Anderson's (2006) study, females in the Control group performed similarly to the punishment aversive females described by Hooper (2004). However, the females in the Attention, Motivation, and Competition groups in Anderson's (2006) study performed as well as or better than the males. According to Anderson (2006), this suggests that females may derive their motivation from more external cues than internal cues. Therefore, there are many potentially confounding cognitive and personality variables which could explain performance differences between men and women on the IGT.

Results of Cognitive Model Analyses

The Expectancy-Valence Learning Model produced a positive G^2 for 43% (76) of the participants in this study. The average G^2 improvement of the Expectancy-Valence Learning Model over the baseline model was 15.24. The negative G^2 for the remaining 57% of the participants indicates that the Expectancy-Valence Learning Model did not succeed in explaining how the participants' choices were dependent on trial-by-trial feedback. Instead, the baseline model, which assumes that the participants' choices are independently and identically distributed across trials, was a better fit for 57% of the participants. If you interpret the baseline model to represent random responding or lack of effort on the IGT, this suggests that slightly over half of the participants were not invested in the task. This indirectly speaks to a potential problem regarding young adult performance on the IGT; that is, that the participants don't care whether they win or lose. Indeed, the mean net score for participants with a positive G^2 was significantly higher than the mean net score for participants with a negative G^2. In fact, the mean net score for participants with a negative G^2 (mean net score= 1.43) was below the net score cutoff for impaired decision-making (Bechara & Damasio, 2002a; 2002b) while the mean net score for participants with a positive G^2 (mean net score= 10.87) was above the cutoff. The range of net scores was the same for both the positive and negative G^2 groups, so some people in each group performed very well while others performed very poorly. This indicates that the Expectancy Valence Learning model's fit is not dependent on whether a participant wins or loses on the IGT. It is possible that the poor IGT performance exhibited by young adults is due in large part to lack of investment in the task. Whether the lack of investment displayed by these young adults is due to underdevelopment of the prefrontal cortex, purposeful lack of attention to the task (they simply didn't care if they performed well), and/or other factors is impossible to discern in the current study.

Because the cognitive model did not fit for 57% of the participants, the analysis of parameter estimates was done on the remaining 74 participants, who were similar to the original 174 participants in terms of age, education, ethnicity, gender, group, and AUDIT risk status.

Recall that large values on the attention parameter (*W*) denote increasing attention to gains while small values denote increasing attention to losses. The current study found that the attention parameter was significantly lower for the Motivation group than for the Control group, indicating that the Motivation group paid more attention to losses than the Control group. Participants who were able to earn real money on the IGT were more attentive to the losses they experienced but this did not translate into higher overall net scores for the Motivation group.

The hypothesis that young adults who have the opportunity to earn real money on the IGT would differ on the response sensitivity/consistency parameter, making more choices from the deck with the maximum expectancy was marginally supported. The difference between groups on the response sensitivity/consistency parameter (*c*) approached significance, suggesting that the Motivation group made choices that were somewhat more sensitive to their expectancies about the decks. Again, the Motivation group did not have a higher mean net score (net score= advantageous choices – disadvantageous choices) than the Control group, but results from this study suggest that they paid more attention to the losses they experienced and that their choices were somewhat more dependent on their expectancies than the Control group.

The hypothesis that young adults who are at-risk for alcohol dependence would differ on the motivation parameter, paying more attention to wins than losses than those who are not at-risk was not supported by these results. Findings from this study suggest that young adults who are at-risk for alcohol dependence do not perform differently on the IGT than young adults who are not at-risk. This is evident even when using the Expectancy-Valence Learning model to examine the performance of these individuals. One possible reason for this is that the IGT measures a different construct than impulsive decision-making in the young adult population. It is also possible that performance on the IGT does not depend on real-world behaviors such as alcohol use.

The purpose of this study was to better understand young adult decision-making. Young adults have a tendency to make risky decisions and engage in dangerous activities far more than younger children or older adults. Congruently, young adults exhibit poor decision-making on the Iowa Gambling Task, which is considered by many to be a laboratory analogue of real-world decision-making (Bechara et al, 2000; Dunn, Dalgleish, & Lawrence, 2006). Therefore, a better understanding of young adults' performance deficits on the IGT could lead to better understanding of their real-world decision-making.

IGT performance is typically analyzed as choice proportions averaged across trials, even though the task provides numerous observations (100 trials) for each participant. The Expectancy-Valence Learning model was designed to analyze the trial-by-trial choices and outcomes on the IGT to gain a better understanding of the intricate cognitive processes that shape an individual's choice behavior (Yechiam, Kanz, Bechara, Stout, Busemeyer, et al., 2008). An important advantage of the Expectancy-Valence Learning model over other types of analyses is that the model provides estimates of cognitive, motivational, and response processes that are estimated directly from the data. This is an exciting and new area of study, and additional research aimed at testing the Expectancy-Valence Learning model in young adult populations is needed.

The use of complex decision-making tasks such as the IGT to mimic real-world decision-making has the potential to improve our understanding of how young people make decisions in their everyday lives. Future studies looking at young adult decision-making should include varied ways to measure risk-taking behaviors. As noted by Steinberg (2008), many of the risky behaviors seen during adolescence are decisions made in a group setting. Undoubtedly this experience is different than sitting in a laboratory making decisions in isolation. In the future, studies should be conducted that take into account group dynamics and their influence on young adult decision-making. Perhaps we will discover that the evolutionarily-adaptive drive to take risks in social situations is the most powerful motivator of all.

References

Allen, J. P., Litten, R. Z., Fertiz, J. B., and Babor, T. (1997). A review of research on the Alcohol Use Disorders Identification Test (AUDIT). *Alcoholism: Clinical and Experimental Research, 21*(4), 613-619.

American Psychiatric Association. (1994). *Diagnostic and Statistical Manual of Mental Disorders.* 4th ed. Washington, DC: American Psychiatric Association.

Anderson, E. J. (2006). Mechanisms of decision-making in young adults: a neurosychological perspective (Doctoral Dissertation, State University of New York at Binghamton, 2006). Dissertation Abstracts International, 67 (03B), 1691.

Anderson, E. J., Castelda, B. A., MacKillop, J., Mattson, R. E., & Donovick, P. J. (2006). Iowa Gambling Task performance in young adults at-risk and not at-risk for alcohol dependence. Unpublished manuscript.

Anderson, E. J., Robeson, K., & Donovick, P. J. (2005). The effects of time on impulsive decision making in a young adult sample. Unpublished manuscript.

Babor, T. F., Higgins-Biddle, J. C., Saunders, J. B., & Monteiro, M. G. (2001). *Alcohol Use Disorders Identification Test: Guidelines for Use in Primary Care*. World Health Organization: Geneva, Switzerland.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50,* 7-15.

Bechara, A. & Damasio, H. (2002a). Decision-making and addiction (part I): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia, 40,* 1675-1689.

Bechara, A., Damasio, H., & Damasio, A.R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10,* 295-307.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A.R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275*, 1293-1295.

Bechara, A., Damasio, H., Tranel, D., & Anderson, S. W. (1998). Dissociation of working memory from decision making within the human prefrontal cortex. *The Journal of Neuroscience, 18,* 428-437.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S., & Nathan, P. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia, 39*, 376-389.

Bechara, A., Dolan, S., & Hindes, A. (2002b). Decision-making and addiction (part II): Impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologica, 40,* 1675-1689.

Bechara, A., Tranel, D., & Damasio, H. (2000b). Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain, 123*(11), 2189-2202.

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral Cortex, 6*(2), 215-225.

Blair, R. J. R., Colledge, E., & Mitchell, D. G. V. (2001). Somatic markers and response reversal: Is there orbitofrontal cortex dysfunction in boys with psychopathic tendencies? *Journal of Abnormal Child Psychology, 29,* 499-511.

Bowman, C. H., & Turnbull, O. H. (2003). Real versus facsimile reinforcers on the Iowa Gambling Task. *Brain and Cognitiion, 53,* 207-210.

Bunge, S. A., Dudovic, N. M., Thomason, M. E., Vaiday, C. J., & Gabrieli, J D. E. (2002). Immature frontal lobe contributions to cognitive control in children: Evidence from fMRI. *Neuron, 33*, 301-311.

Busemeyer, J. R. & Myung, I. J. (1992). An adaptive approach to human decision making: learning theory, decision theory, and human performance. *Journal of Experimental Psychology: General, 121*(2), 177-194.

Busemeyer, J. R. & Stout, J. C. (2002). A contribution of cognitive decision models to clinical assessment: decomposing performance on the Bechara Gambling Task. *Psychological Assessment, 14*(3), 253-262.

Cavedini, P., Riboldi, G., D'Annucci, A., Belotti, P., Cisima, M., & Bellodi, L. (2002). Decision-making heterogeneity in obsessive-compulsive disorder: Ventromedial prefrontal cortex function predicts different treatment outcomes. *Neuropsychologia, 40*, 205-211.

Damasio, A. R. (1994). *Descartes' Error: Emotion, reason, and the human brain*. New York: Avon books.

Damasio, A. R. (1998). The somatic marker hypothesis and the possible functions of the prefrontal cortex. In Roberts, A. C., Robbins, T. W. (Eds), et al. The prefrontal cortex: Executive and cognitive functions. London: Oxford University Press.

Dunn, B. D, Dalgleish, T., & Lawrence, A. D. (2006). The somatic marker hypothesis: A critical evaluation. *Neuroscience and Biobehavioral Reviews, 30*, 239-271.

Eaton, D. K., Kann, L., Kinchen, S., Ross, J., Hawkins, J., Harris, W. A., et al. (2006). Youth Risk Behavior Surveillance- United States, 2005. *Journal of School Health, 76*(7), 353-372.

Elliott, R., Dolan, R. J., & Frith, C. D. (2000). Dissociable functions in the medial and lateral orbitofrontal cortex: Evidence from human neuroimaging studies. *Cerebral Cortex*, *10*, 308-317.

Ernst, M. & Paulus, M. P. (2005). Neurobiology of decision making: a selective review from a neurocognitive and clinical perspective. *Biological Psychiatry, 58*(8), 597-604.

Fleming, M. F., Barry, K. L., & MacDonald, R. (1991). The alcohol use disorders identification test (AUDIT) in a college sample. *International Journal of the Addictions, 26*, 1173-1185.

Giedd, J. N., Snell, J., Lange, N., Rajapakse, J., Casey, B. J., Kozuch, P., et al. (1996). Quantitative magnetic resonance imaging of human brain development: Ages 4-18. *Cerebral Cortex, 6*, 551-560.

Grant, S., Contoreggi, C., & London, E. D. (2000). Drug abusers show impaired performance in a laboratory test of decision-making. *Neuropsychologia, 38*, 1180-1187.

Hays, R. D., Merz, J. F. & Nicholas, R. (1995). Response burden, reliability, and validity of the CAGE, Short MAST, and AUDIT alcohol screening measures. *Behavioral Research Methods, Instruments, and Computers, 27*, 277-280.

Hooper, C. J., Luciana, M., Conklin, H. M., & Yarger, R. S. (2004). Adolescents' performance on the Iowa Gambling Task: Implications for the development of decision making and ventromedial prefrontal cortex. *Developmental Psychology, 40*(6), 1148-1158.

Johnson, S. A., Yechiam, E., Murphy, R., Stout, J. C., & Busemeyer, J. R. (2004, May). *A formal decision model: Application to Asperger's disorder*. Paper presented at the International Meeting for Autism Research, Sacramento, CA.

Lane, S. D., Yechiam, E., & Busemeyer, J. R. (2006). Application of a computational decision model to examine acute drug effects on human risk taking. *Experimental and Clinical Psychopharmacology, 14*(2), 254-264.

London, E.D, Ernst, M, Grant, S., Bonson, K., & Weinstein, A. (2000). Orbitofrontal cortex and human drug abuse: Functional imaging. *Cerebral Cortex, 10,* 334-342.

MacKillop, J., Mattson, R. E., Anderson, E. J., Castelda, B. A., & Donovick, P. J. (2007). Multidimensional assessment of impulsivity in undergraduate hazardous drinkers and controls. *Journal of Studies on Alcohol and Drugs, 68*(6), 785-788.

Maggs, J. L., Almeida, D. M., & Galambos, N. L. (1995). Risky business: The paradoxical meaning of problem behavior for young adolescents. *Journal of Early Adolescence, 15*, 344-362.

MathWorks Inc. (2000). Matlab: The language of technical computing [Computersoftware]. Natick, MA: Mathworks Inc.

Mukherjee, P., Miller, J. H., Shimoney, J. S., Philip, J., Nehra, D., Snyder, A. Z., et al. (2002). Diffusion tensor MR imaging of gray and white matter delvopment during normal human brain maturation. *American Journal of Neuroradiology, 23*, 1445-1456.

Overman, W. H., Frassrand, K., Ansel, S., Trawalter, A., Bies, B., & Redmond, A. (2004). Performance on the Iowa card task by adolescent and adults. *Neurosychologia, 42*, 1838-1851.

Petry, N. M., Bickel, W. K., & Arnet, M. (1998). Shortened time horizons and insensitivity to future consequences in heroin addicts. *Addiction, 93*, 729-738.

Petry, N. M. (2001). Substance abuse, pathological gambling, and impulsiveness. *Drug and Alcohol Dependence, 63*, 29-38.

Reinert, D. F., & Allen, J. P. (2002). Alcohol Use Disorders Identification Test (AUDIT): A review of recent research. *Alcoholism- Clinical and Experimental Research, 26*(2), 272-279.

Reyna, V. F. & Farley, F. (2006). Risk and rationality in adolescent decision making- Implications for theory, practice, and public policy. *Psychological Science, 1-44 Suppl. S, Sept 2006.*

Rogers, R. D. & Robins, T. W. (2001). Investigating the neurocognitive deficits associated with chronic drug misuse. *Current Opinions in Neurobiology, 11*, 250-257.

Sowell, E. R., Thompson, P. M., Holmes, C. J., Jernigan, T. L., & Toga, A. W. (1999). In vivo evidence for post-adolescent brain maturation in frontal and striatal regions. *Nature Neuroscience, 2,* 85-861.

Sowell, E. R., Thompson, P. M., Tessner, K. D., & Toga, A. W. (2001). Mapping continued brain growth and gray matter density reduction in dorsal frontal cortex: Inverse relationships during postadolescent brain maturation. *The Journal of Neurosicence, 21*, 8819-8829.

Spear, L. P. (2000). The adolescent brain and age-related behavioral manifestations. *Neuroscience and Biobehavioral Reviews, 24*, 417-463.

Spear, L.P. (2002). The adolescent brain and the college drinker: biological basis of propensity to use and misuse alcohol. *Journal of Studies on Alcohol, 14*, 71-81.

Stallen, M. (2006). Excel® application of the Expectancy-Valence model. Technical Report, University of Amsterdam.

Steinberg, L. (2004). Risk taking in adolescence- What changes, and why?. A*nnals New York Academy of Sciences*, *1021*, 51-58.

Steinberg, L. (2007). Risk taking in adolescence- New perspectives from brain and behavioral science. *Current Directions in Psychological Science, 16*(2), 55-59.

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review, 28*, 78-106.

Stout, J. C., Busemeyer, J. R., Lin, A., Grant, S. J., & Bonson, K. R. (2004). Cognitive modeling analysis of decision-making processes in cocaine abusers. *Psychonomic Bulletin & Review, 11*(4), 742-747.

Stout, J. C., Rock, S. L., Campbell, M. C., Busemeyer, J. R., & Finn, P. R. (2005). Psychological processes underlying risky decisions in drug abusers. *Psychology of Addictive Behaviors, 19*(2), 148-157.

Stout, J. C., Rodawalt, W. C., & Siemers, E. R. (2001). Risky decision making in Huntington's disease. *Journal of the International Neuropsychological Society, 7*, 92-101.

Yechiam, E., Busemeyer, J. R., Stout, J. C., & Bechara, A. (2005). Using cognitive models to map relations between neuropsychological disorders and human decision-making deficits. *Psychological Science, 16*(12), 973-978.

Yechiam, E., Kanz, J. E., Bechara, A., Stout, J. C., Busemeyer, J. R., Altmaier, E. M., & Paulsen, J. S. (2008). Neurocognitive deficits related to poor decision making in people behind bars. *Psychonomic Bulletin & Review, 15*(1), 44-51.

Yechiam, E., Stout, J. C., Lamborn, C., Mussat-Whitlow, B. J., Liguori, A., & Porrino, L.J. (2004, April). *Differential influence of marijuana on decision processes in the Bechara gambling task.* Poster presented at the annual meeting of the Cognitive Neuroscience Society, San Fransisco.

APPENDIX A

AUDIT

1. How often do you have a drink containing alcohol?

Never	Monthly Or less	2-4 times a month	2-3 times a week	4 or more times a week

2. How many drinks containing alcohol do you have on a typical day when you are drinking?

1 or 2	3 or 4	5 or 6	7 to 9	10 or more

3. How often do you have six or more drinks on one occasion?

Never	Monthly Or less	2-4 times a month	2-3 times a week	Daily or almost daily

4. How often during the last year have you found that you were not able to stop drinking once you started?

Never	Monthly Or less	2-4 times a month	2-3 times a week	Daily or almost daily

5. How often during the last year have you failed to do what is normally expected from you because of drinking?

Never	Monthly Or less	2-4 times a month	2-3 times a week	Daily or almost daily

6. How often during the last year have you needed a first drink in the morning to get yourself going after a heavy session?

Never	Monthly Or less	2-4 times a month	2-3 times a week	Daily or almost daily

7. How often in the last year have you had a feeling of remorse or guilt after drinking?

Never	Monthly Or less	2-4 times a month	2-3 times a week	Daily or almost daily

8. How often during the last year have you been unable to remember what happened last night because of your drinking?

Never	Monthly Or less	2-4 times a month	2-3 times a week	Daily or almost daily

9. Have you or someone else been injured because of your drinking?

No	Yes, but not in the past year	Yes, during the past year

10. Has a relative, friend, doctor, or other health care worker been concerned about your drinking or suggested you cut down?

No	Yes, but not in the past year	Yes, during the past year

APPENDIX B

IGT Standard Administration Instructions

"In front of you on the screen there are four decks of cards: A, B, C, D.

I want you to select one card at a time, by clicking on the card, from any deck you choose.

Each time you select a card, the computer will tell you that you won some money. I don't know how much money you will win. You will find out as we go along. Every time you win, the green bar gets bigger.

Every so often, however, when you click on a card, the computer tells you that you won some money, but then it says that you lost some money too. I don't know when you will lose, or how much you will lose. You will find out as we go along. Every time you lose, the green bar gets smaller.

You are absolutely free to switch from one deck to the other at any time, and as often as you wish.

The goal of the game is to win as much money as possible, and if you can't win, avoid losing money as much as possible.

You won't know when the game will end. You must keep on playing until the computer stops.

I am going to give you this $2000 credit, the green bar, to start the game. The red bar here is a reminder of how much money you borrowed to play the game, and how much money you have to pay back before we see how much you won or lost.

It is important to know that just like in a real card game the computer does not change the order of the cards after the game starts. You may not be able to figure out exactly when you will lose money, but the game is fair. The computer does not make you lose money at random, or make you lose money based on the last card you picked. So you must not try to figure out what the computer is doing. All I can say is that some decks are worse than others. No matter how much you find yourself losing, you can still win if you stay away from the worst decks. Please treat the play money in this game as real money, and any decision on what to do with it should be made as if you were using your own money. Are there any questions? Ready? Begin."

APPENDIX C

IGT Motivation Condition Administration Instructions

Italics represent changes from originally published protocol (Bechara et al., 2000)

“In front of you on the screen there are four decks of cards: A, B, C, D.

I want you to select one card at a time, by clicking on the card, from any deck you choose.

Each time you select a card, the computer will tell you that you won some money. I don’t know how much money you will win. You will find out as we go along. Every time you win, the green bar gets bigger.

Every so often, however, when you click on a card, the computer tells you that you won some money, but then it says that you lost some money too. I don’t know when you will lose, or how much you will lose. You will find out as we go along. Every time you lose, the green bar gets smaller.

You are absolutely free to switch from one deck to the other at any time, and as often as you wish.

The goal of the game is to win as much money as possible, and if you can’t win, avoid losing money as much as possible.

You won’t know when the game will end. You must keep on playing until the computer stops.

I am going to give you this $2000 credit, the green bar, to start the game. The red bar here is a reminder of how much money you borrowed to play the game, and how much money you have to pay back before we see how much you won or lost.

It is important to know that just like in a real card game the computer does not change the order of the cards after the game starts. You may not be able to figure out exactly when you will lose money, but the game is fair. The computer does not make you lose money at random, or make you lose money based on the last card you picked. So you must not try to figure out what the computer is doing. All I can say is that some decks are worse than others. No matter how much you find yourself losing, you can still win if you stay away from the worst decks.

See on the screen where it says you begin with $2000? Since we cannot afford to give you $2000 to start, we will divide that amount by 1000 and give you $2.00. Every $1000 *on the screen= $1.00 to you. Now, you have the opportunity to win as much money as possible, remembering that the dollar amount you see on the screen will be divided by 1000 and given to you. Say for example, it says you win $500. How much money would that be to you? Right, 50 cents. (Or No, see, $5000 divided by 10000 is .5, or 50 cents.) You have the opportunity to double your money or lose all of it. You will not be expected to pay any money if you go in the hole.*

Finally, at the end of the game, your winnings will be tallied. If you win more than $1500, you will win a cash prize of $5 today in addition to your other winnings.

Are there any questions? Ready? Begin."

APPENDIX D

Research Participant Consent Statement

Project Director of Principal Investigator: Emily J. Anderson, MA & Lori Wagner
Title of Project: Gambling Behavior in College Students

You are invited to participate in a research study of gambling behavior. We hope to learn how college students make judgments when gambling. You were selected to participate in this study because you are currently enrolled at Binghamton University.

If you decide to participate, we will ask to affix two electrodes to your non-dominant palm to measure your emotional response to a computerized gambling game. We do not expect for you to experience any discomfort from this, and you may participate in the study without this measurement. We will also ask you to fill out two questionnaires. The experiment will take approximately 30 minutes. There are no anticipated risks. In terms of benefits, you will receive ½ research credit and possibly some monetary compensation, and we hope, an informative experience participating in psychological research.

All of the personal and identifying information you provide during this study will be kept confidential. We will not disclose this information to anyone. Your decision whether or not to participate will not prejudice your future relations with the Environmental Neuropsychology Laboratory, or SUNY Binghamton. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without prejudice.

Before you sign the form, please ask questions on any aspect of the study that is at all unclear to you. If you have any additional questions later, Dr. Peter Donovick (777-2852), Emily Anderson (777-2855), or Lori Wagner (777-2855) will be happy to answer them. If at any time you have questions concerning your rights as a research subject you may call the Chair of Binghamton's Human Subject Research Review Committee, Dr. Gary James, at (607) 777-6086. You will be given a copy of this form to keep.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

Date ______________ Time _____________ AM/PM

Signature ____

Signature of Witness __________________Signature of Investigator _______________