NEUROPSYCHOLOGICAL CORRELATES OF RISK-TAKING BEHAVIOR IN AN UNDERGRADUATE POPULATION

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NEUROPSYCHOLOGICAL CORRELATES OF RISK-TAKING BEHAVIOR IN AN
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In the college age population, risk-taking behavior has become common in the form of drug and alcohol abuse, dangerous physical activities, and unsafe sexual practices. Previous theories that have explored the factors involved in such behaviors include dispositional, decision-making, and neurocognitive functioning based theories. The present study examined the contributions of gender, disposition, affect, and executive functions involved in decision-making, to self-reported expected participation in risk-taking activities in undergraduates from a mid-sized Midwestern university (N=90). Individuals were assessed using the Iowa Gambling Task, the Go/No Go test, and the Wisconsin Card Sorting Test. Participants were administered the Positive Affect Negative Affect Schedule, a self-report measure based on Gray’s behavioral activation/behavioral inhibition systems theory (BIS/BAS scale), and a self-report measure of expected participation in risk-taking behavior (Cognitive Appraisal of Risky Events Scale). In the full sample, gender was found to be the best predictor of risk-taking. Males and females were then examined individually, and for the male sample, worse performance on measures of executive functioning was associated with more expected participation in risk-taking. In the full sample, a relationship was found between a higher BAS to BIS system ratio and worse performance on the gambling task compared to individuals with a relative balance or a higher BIS to BAS ratio. Some support was found
for the role of psychophysiological responsiveness during Gambling Task performance; however, a clear role between amount of responsiveness and level of Gambling Task performance was not found. Finally, a new method of collecting psychophysiological data for the Gambling Task was explored and supported. The findings indicate that dispositional variables play an important role in Gambling Task performance and risk-taking behavior. Affect is an important factor in Gambling Task Performance, but the role of physiological responsiveness is less clear.

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Introduction

Risk-taking behaviors are prevalent in society despite knowledge of their serious consequences. For example, tobacco use contributes to over 450,000 deaths annually and is the leading cause of preventable mortality and health expense in the United States (Centers for Disease Control and Prevention [CDC], 1994). In the United States, the leading cause of death is coronary heart disease, and 1,000,000 individuals experience a recurrent or initial coronary event (American Heart Association, 2001). Yet there are three major modifiable risk factors for coronary disease: smoking, activity level, and diet (Smith & Ruiz, 2002). In college populations, 50% of students surveyed report having driven while intoxicated (Fromme, Katz, & Rivet, 1997). In a recent survey, 82% of college students reported being sexually active, 44% reported having two or more partners, and 75% reported not always practicing safe sex (Fromme et al., 1997). All of these situations involve behaviors with known negative consequences, yet those consequences do not seem effective at influencing individuals to change their behavior.

Rational thought would suggest an individual would not do what they know to be bad for them, but any quick review of the literature on smoking or drug and alcohol use reveals that education campaigns are not particularly effective at preventing such behaviors and have limited effectiveness in stopping them (Niaura & Abrams, 2002; Miller, Brown, Simpson, Handmaker, Bien, Luckie, Montgomery, Hester & Tonigan, 1995). Decision-making and risk-taking behavior involve multiple components that interact in complex ways. Research aimed at uncovering these complex processes could
potentially lead to better methods of preventing and treating a variety of behavior-based problems.

Current research on risk-taking behavior has borrowed heavily from the decision-making literature. The historical background of decision-making research is grounded in a rational tradition. However, research on rational thought in decision-making situations has led to consistent findings that people violate principles of logic (Tversky & Kahneman, 1974). For example, one of the major theories of decision-making under risk is the expected utility model (Fishburn, 1970). According to this theory, a decision maker, when faced with a choice, will prefer the prospect that offers the highest expected utility. Expected utility theory has required modification because research has consistently shown that people exhibit patterns of choice incompatible with the theory (Tversky & Kahneman, 1974). Expected utility theory is the most well-known model proposing rational thought as the basis for decision-making. However, this theory is unable to fully account for people’s patterns of preference in decision-making situations. This theory is also inadequate at explaining why people regularly engage in health damaging activities despite clear knowledge of the consequences of such behavior. Perhaps risk-taking behavior needs to be examined in a multidimensional manner. Important additional dimensions may include dispositional variables related to reward and punishment sensitivities, affect, and cognitive variables. Furthermore, these factors may be related to functioning of the prefrontal cortex and make up a multi-component decision-making system.

The goal of the current study was to begin identifying critical variables related to risk-taking behavior in the dispositional, cognitive, and affective domains. This required
an examination of the existing research behind these models and an integration of
approaches, with the goal of a more unified explanation of the factors involved in risk-
taking behavior. For the purposes of this study, measures of executive functioning,
autonomic responses, affect, and disposition were used to represent the relevant domains
with a hypothesized relationship to risk-taking in an undergraduate population.

Dispositional Theories of Risk-Taking

Dispositional theories have provided some understanding of individual
differences in risk-taking behavior. Many of these theories have focused on a biological
basis for dispositional traits, and attempts to tie aspects of these theories to biological
processes have led to mixed results.

*Eysenck’s Introversion and Extraversion*

The classic example of this type of theory comes from Eysenck (1967), who
proposed that the difference between introverts and extraverts could be explained by
differences in the ascending reticular activating system (ARAS). The ARAS is a series of
ill-defined nuclei located through the length of the brain stem that is involved in
activation and deactivation of the cerebral cortex. The ARAS is involved in controlling
the sleep cycle and maintaining alertness and concentration. When the ARAS is
functioning at a high level, the individual is alert. However, when it is functioning at a
low level, the individual is sluggish. According to Eysenck, introverts have a higher
level of cortical arousal as a result of their ARAS letting in too much stimulation. The
resulting behavior (being quiet and seeking low-stimulation settings) is an attempt by the
introvert to keep their already heightened arousal level under control. For extraverts, there is not enough arousal, so they engage in behaviors such as sensation seeking in an attempt to increase arousal.

The physiological basis of Eysenck’s theory has little empirical support. The most widely cited study to offer evidence for the neurobiological basis of the theory was conducted by Geene (1984). The purpose of this study was to examine differences in arousal levels between introvert and extraverts by comparing the group’s preferred noise level. Extraverts preferred a significantly higher mean volume level compared to introverts. When introverts were placed in an extravert’s preferred noise level, there was a significant increase in heart rate and skin conductance response, and when extraverts were placed in an introvert’s preferred noise level, there was a significant decrease in heart rate and skin conductance response. The major limitation of this study is that brain areas involved in arousal were not studied directly and therefore, no specific conclusions can be reached with regard to the physiological mechanisms Eysenck suggests.

Zuckerman’s Impulsive Sensation-Seeking

Eysenck’s theory relied heavily on Hebb’s theory of optimal level of arousal. This theory posits that people are motivated to reach an optimal level of cortical and physiological arousal. Another dispositional researcher who utilizes this theory is Zuckerman (1991) in his work on sensation-seeking. Like Eysenck, Zuckerman theorized that sensation seekers require a lot of stimulation in order to reach their optimal level of arousal. Zuckerman’s research eventually led to examining neurotransmission as a possible explanation for sensation-seeking behavior. He concluded that sensation seekers had lower levels of monoamine oxidase (MAO), which results in more monoaminergic
neurotransmitter being available. By breaking down neurotransmitters such as dopamine and serotonin, MAO regulates the amount of neurotransmitter levels and keeps the nervous system working properly. According to Zuckerman (1991), sensation-seeking behavior is the result of low MAO levels, leading to less inhibition in the nervous system and less control over behavior, thoughts and emotions. Research suggests that MAO levels are related to social dominance, sociability and aggression (Rowe, 2001), and a gene related to MAO levels has been linked to aggression and impulsivity (Manuck, Flory, Ferrell, Mann, & Muldoon, 2000). Zuckerman later combined the constructs of impulsivity and sensation-seeking as a result of high correlations between self-report measures of the two constructs and the fact that they both predict the same kind of behavior and biological traits (Zuckerman, 1994).

Most of Zuckerman’s early research used the Sensation-Seeking Scale (SSS, Zuckerman, 1979). The SSS consists of 40 forced choice items yielding four subscale scores, Thrill and Adventure Seeking, Experience Seeking, Disinhibition, Boredom Susceptibility, and a total score based on the sum of the subscales. Research has found a relationship between the SSS and a variety of risk-taking behaviors. For example, a study on risky behavior in an undergraduate population found that perceived peer behavior had the strongest relationship to risk-taking behavior, but the next strongest relationship was sensation seeking, which was particularly strong for crime and minor violations. A study by O’Sullivan, Zuckerman & Kraft (1996) compared female prostitutes and controls on the Zuckerman-Kuhlman Personality Questionnaire (ZKPQ). The ZKPQ is a 99-item true/false inventory that measures five dimensions of personality: 1) Impulsive Sensation-Seeking; 2) Neuroticism-Anxiety; 3) Aggression-Hostility; 4) Activity; and
5) Sociability. The prostitute group was significantly higher than controls on Impulsive Sensation-Seeking. Analysis of differences within the prostitute group revealed that cocaine users among the prostitutes scored significantly higher than other drug and non-drug using prostitutes on Impulsive Sensation-Seeking. Polydrug users scored significantly higher on Impulsive Sensation-Seeking than non-drug and one-drug users. The authors pointed out that these results are based on small sample sizes, and there are also potential problems with the trustworthiness of the prostitutes’ reports of drug use (O’Sullivan et al., 1996). A recent study found that individuals high in Impulsive Sensation-Seeking were more interested in gambling than those classified as low and medium on the scale (McDaniel & Zuckerman, 2003). The sample was divided into five age groups (18-24, 25-34, 35-44, 45-64, and 65+). These studies taken together clearly point to a significant relationship between sensation-seeking and risk-taking behavior. However, the research on MAO and sensation-seeking, while promising, is not conclusive at this time.

*Cloninger’s Tridimensional Model*

Another personality theory based on neurotransmitter activity comes from Cloninger (1987). Cloninger’s model, the Tridimensional Personality model, ties three personality traits to levels of three neurotransmitters. The first trait, novelty-seeking, is hypothesized to be the result of low levels of dopamine. The result is a drive to ingest substances or partake in experiences that increase dopamine levels, such as novelty, thrills and excitement. Evidence for this relationship comes from research that has implicated dopamine as part of the reward system (Hamel, 1997). It has also been well
established that drugs of abuse (cocaine) mimic dopamine in the nervous system and result in the pleasure associated with taking them (Dackis & Mark, 1985).

The second trait, harm avoidance, is hypothesized to be associated with low levels of serotonin. The result, according to Cloninger, is sensitivity to unpleasant events or to stimuli or events that have become associated with punishment or pain. Evidence for the relationship between harm avoidance and serotonin comes from both human and animal research. For example, a study by Knutson, Wolkowitz, Cole, Chan, Moore, Johnson, Terpestra, Turner and Reus gave Prozac (a selective serotonin reuptake inhibitor) to a group of non-depressed participants (1998). Over several weeks of observation, this group reported less negative affect and engaged in more outgoing and social behavior than the control group (Knutson et al., 1998). Animal research has shown that monkeys higher in dominance and that engaged in more grooming had higher levels of serotonin, and monkeys low in serotonin were often fearful and aggressive (Rogness & McClurer, 1996).

The third trait in this model is reward dependence. Cloninger associates reward dependence with low levels of norepinephrine. Norepinephrine is involved in activating the sympathetic nervous system for fight-or-flight. This trait is associated with persistence, as according to Cloninger, people high in this trait will maintain high effort in order to produce a reward. Currently, there is limited research to establish anything other than a speculative relationship between norepinephrine and reward dependence.

Gray’s Behavioral Activation/Behavioral Inhibition Systems

One of the most influential biological theories of personality comes from Jeffrey Gray (1972, 1990). Gray’s theory, named Reinforcement Sensitivity Theory, is based on
two hypothesized biological systems in the brain. Gray theorizes that impulsivity and anxiety represent fundamental dimensions of temperament (Pickering & Gray, 1999). Individual differences along these dimensions reflect variation in the reactivity and/or sensitivity of the two hypothesized systems to their specific classes of stimuli. Gray’s two systems are the behavioral activation system (BAS), which is associated with impulsivity, and the behavioral inhibition system (BIS), which is associated with anxiety. These systems respond to different classes of reinforcing stimuli. The BAS is activated by conditioned stimuli signaling reward or relief from punishment and the BIS is activated by novel stimuli and by conditioned stimuli signaling punishment or frustrative nonreward.

According to this theory, the BAS and BIS are in competition with one another for control over behavior (Gray & Smith, 1969). The BAS can be conceptualized as a “go” system that, when activated, motivates the person to engage in approach behavior. The BIS can be thought of as a “stop” system that, when activated, motivates the inhibition of behavior and thereby allows further information processing. This theory states that the BIS response is appropriate under activating conditions that involve signals of punishment and/or loss of reward, warning of negative consequences.

In order to better understand the functions of the BAS/BIS systems, it is helpful to explore four behavioral paradigms (Fowles, 2001). The first paradigm is a reward paradigm where the organism learns to respond to get a reward. In this paradigm, conditioned stimuli associated with reward exert their control over behavior through the BAS. The second paradigm is an active avoidance paradigm. In this paradigm, the conditioned stimulus is paired with something aversive. As a result, the avoidance
response is activated by the BAS in response to conditioned stimuli for nonpunishment (Fowles, 2001).

Two other paradigms involve mutual antagonism between the BAS and the BIS. The extinction paradigm involves the nonoccurrence of an expected reward and produces frustration (Fowles, 2001). Stimuli in this paradigm become conditioned stimuli for frustration and activate the BIS, resulting in inhibition of the approach response. The BIS activity needs to be strong enough to inhibit the approach response. This occurs as the nonreward conditioned stimulus increases in strength over extinction trials.

The last paradigm, which best represents what happens in risk-taking situations, is the approach-avoidance paradigm. In this paradigm, punishment is introduced once the reward response has been established. The introduction of punishment increases the likelihood of passive avoidance and can be attributed to BIS inhibition of the approach system in response to conditioned stimuli for punishment. In this paradigm, the BIS and BAS act in opposition to each other, with the BAS activating approach behavior in response to conditioned stimuli for reward and the BIS inhibiting those responses when presented with conditioned stimuli for punishment. The response that will occur depends on the relative strength of each of these systems. It has been proposed that this outcome is determined by the relative strength of the reward conditioned stimuli and punishment conditioned stimuli inputs (Fowles, 2001).

Gray (1987) uses four terms to refer to the motivational states created by these four paradigms. For the two aversive motivational states he uses the terms “frustration” (for nonreward conditioned stimuli) and “fear or anxiety” (for punishment conditioned
The two-appetitive motivational states are “hope” (for the reward conditioned stimuli) and “relief” (for the nonpunishment conditioned stimuli).

Gray has theorized that the neural basis for the BIS centers on the septohippocampal system (1987). Specifically, Gray believes that the BIS involves control of hippocampal theta activity by a pacemaker in the medial septal area and also includes the Papez loop, noradrenergic pathways that ascend from the locus coeruleus to the septohippocampal system, serotinergic pathways that ascend from the raphe nuclei to the septohippocampal system, and neocortical structures (including the prefrontal cortex) that have bi-directional connections to the septohippocampal system. The septohippocampal system compares actual stimuli with expectations. When there is a discrepancy, or a signal for nonreward or punishment, the septohippocampal system takes control and activates the BIS.

The BAS is hypothesized to involve dopaminergic pathways (Gray, 1987). There is evidence that the mesolimbic DA pathway that ascends in the ventral tegmental area to the nucleus accumbens and the ventral striatum is involved in incentive motivation (Fowles, 2001). The mesolimbic DA system has been implicated in drug abuse (Koob & Le Moal, 1997), and affective disorders (Depue & Iacono, 1989). In the case of both drug abuse and affective disorders, the DA system is believed to activate behavior in response to reward cues (Fowles, 2001). As cited earlier, the relationship between drugs of abuse, such as cocaine, and activation of the DA system is well established (Dackis & Gold, 1985). Figure 1 represents a simple conceptual nervous system diagram for the BAS and BIS (from Pickering and Gray, 1999). Gray interprets this diagram as a model for a neural network.
Figure 1. BIS/BAS Diagram

Note. All arrows represent excitatory pathways except where a minus sign indicates an inhibitory pathway. Arrows with a rounded end indicate a learned input.

Gray’s theory has been influential not only in the study of personality but also in understanding the relationship between personality and psychopathology. For example, in this model, substance abuse can be conceptualized as dominance of the BAS over the BIS, resulting in an impulsive temperament and a motivational bias toward the positive
reinforcement resulting from the effects of the drug. The negative effects of the drugs tend to be delayed and are unable to effectively deter the behavior in the BAS-driven individual.

It is important to acknowledge that Gray’s theory has developed out of animal research and there is limited human research to provide evidence in its favor. Some researchers have attempted to construct questionnaires to measure BIS/BAS sensitivities. MacAndrew Steele created a questionnaire to measure BIS sensitivity (1991). The questionnaire was effective at discriminating between a hypothesized high BIS group (psychiatric patients with a history of panic attacks and anxiety), and low BIS group (prostitutes). Although this scale discriminated between these two groups, it is worth noting that these are extreme groups and the limited follow-up research on this scale does not allow any conclusions regarding its use in measuring individual differences in BIS sensitivities.

Carver and White (1994) also developed a scale to assess dispositional BIS and BAS sensitivities. Carver and White point out that previous BIS measures, as well as anxiety measures, focus on average anxiety level and not vulnerability to anxiety. It has been pointed out that high BIS individuals may become efficient at avoiding anxiety-provoking situations and as a result, experience relatively little anxiety (Fowles, 1987). Carver and White set out to develop a scale that would measure BIS/BAS sensitivities by assessing responses to sets of situations rather than assessing affective tone (1994). Their scale consists of 20 statements, such as “When I get something I want, I feel excited and energized,” that are rated on a 4-point Likert type scale. Factor analysis of the 20 items on a sample of 732 college students yielded four factors; 1) BIS, 2) BAS Reward
Responsiveness, 3) BAS Drive, and 4) BAS Fun Seeking. Internal reliabilities ranged from .66 to .76.

A 1998 study by Zinbarg and Mohlman used the Carver and White BIS/BAS scale to test predictions made by BIS/BAS theory regarding acquisition of punishment and reward expectancies. They hypothesized that, according to Gray’s theory, trait anxiety should be positively related to the speed of acquisition of punishment expectancies and impulsivity should be positively related to speed of acquisition of reward expectancies. Participants in the main condition took part in an approach-avoidance discrimination task. Participants were required to discriminate cues that signaled that pressing a “3” on the computer keyboard would result in winning 25 cents from cues that pressing the response key would result in losing 25 cents. An ego-threat condition replaced the 25 cents with two bogus IQ points. In addition, the participants in the ego-threat condition were told that the experiment was designed to study the relationship between personality and IQ and that the discrimination task assessed IQ. The discrimination cues were two-digit numbers. A total of 12 cues were used, 6 for each group. Cues were presented in blocks of 12 with a total of 6 trials. Half of the participants were randomly assigned to perform a version of the task that required them to complete a self-report measure of expectancies regarding whether they believed that pressing a certain key would lead to winning or losing money (by rating their belief on a 9-point scale) before the start of the task and then after each block of trials. One hundred ninety-nine undergraduates completed the discrimination task and the Trait Anxiety scale from the State Trait Anxiety Inventory (STAI), the Imp subscale from the EPI, and the BIS/BAS scales.
Results showed that the BIS scale correlated significantly with the speed of acquiring punishment expectancies, but not reward expectancies. None of the other personality variables correlated significantly with speed of acquiring punishment expectancies. In addition, when BIS and STAI were entered into a multiple regression as predictors of acquisition of punishment expectancies, BIS scores made a significant unique contribution, but the STAI did not. However, BIS did not predict acquisition of punishment expectancies in the monetary condition of the discrimination task. Analysis of the linear trend of key press responding to punishment and reward cues revealed a non-significant and weak negative correlation for both the monetary and ego-threat conditions. There was no relationship between the linear trend of punishment expectancies and reward expectancies in either condition. This study provides some evidence for individual differences in BIS levels as influencing the acquisition of punishment expectancies. Furthermore, the independent functioning of appetitive and aversive learning demonstrated in this study is consistent with BIS/BAS theory and provides evidence against a single factor such as conditionability (Zinbarg & Mohlman, 1996). This study also provides some evidence for the BIS construct in a normal human population.

Comparison of Theories

The theories of Eysenck, Zuckerman, and Cloninger all point to several dispositional factors that make up personality. The theories are similar in that they all have dimensions that account for risk-taking behavior. For example, Eysenck’s Extraversion, Zuckerman’s Impulsive Sensation-Seeking, and Cloninger’s Novelty-Seeking all describe a personality style prone to engaging in risk-taking behaviors, and
each theory attaches this tendency to a dispositional/biological origin. This raises the question of whether their theories are describing the same disposition. A study by Zuckerman and Cloninger examined the relationship between Cloninger’s, Zuckerman’s and Eysenck’s dimensions of personality (1996). Undergraduate participants were administered the Eysenck Personality Questionnaire Revised (with four factor analytically derived scales: Extraversion, Neuroticism, Psychoticism, and Lie), the Zuckerman-Kuhlman Personality Questionnaire and the Temperament and Character Inventory (Cloninger, Przybeck, Svrakic & Wetzel, 1994; a 125 item self-report scale that includes four temperament scales: Novelty-Seeking, Harm Avoidance, Reward Dependence, and Persistence). Three of the Temperament and Character Inventory scales and the Zuckerman-Kuhlman Personality Questionnaire scales correlated at or above 0.60 (Novelty-Seeking and Impulsive Sensation-Seeking, Harm Avoidance and Neuroticism-Anxiety, and a negative correlation between Cooperativeness and Aggression-Hostility). Correlations between the Temperament and Character Inventory and the Eysenck Personality Questionnaire-R scales indicated a moderate relationship between Novelty-Seeking, Psychoticism, and Extraversion; and Harm Avoidance, Extraversion, and Neuroticism. Given the similarity in content, it is not surprising that the Novelty-Seeking and Impulsive Sensation-Seeking scales were so highly correlated. In addition, both scales have been shown to correlate negatively with MAO. This research suggests that novelty seeking and impulsive sensation-seeking are most likely the same construct and seem to represent a major dimension of personality.

The theories discussed here all involve dispositional variables or personality traits that are hypothesized to have a biological basis. Research on these theories indicates that
these personality traits are associated with a variety of behaviors, including risk-taking behaviors. In fact, each of these theories has a specific way of conceptualizing risk-taking behaviors. For Eysenck, they are the result of the extravert seeking out ways to increase cortical arousal (1967). Geene’s study provided evidence that extraverts do prefer higher levels of stimulation. The studies based on Zuckerman’s model suggest a relationship between Impulsive Sensation Seeking and a variety of risk-taking behaviors. It can be argued that Impulsive Sensation-Seeking is a specific aspect of extraversion. As with other research in this area, these studies depend on individuals’ self-identification of sensation-seeking behavior by endorsing items on a self-report scale. This method can result in strong associations due to shared method variance. It should come as no surprise that people who identify themselves as sensation-seekers on a self-report scale would also endorse risk-taking items on a questionnaire or during an interview. Although this research suggests a definite pattern of individual differences in Impulsive Sensation-Seeking that is related to a variety of risk-taking behaviors, it does not provide a lot of insight into the underlying causes of Impulsive Sensation-Seeking. In addition, Zuckerman’s theory of low MAO levels in high sensation seekers is based on studies that show a small to moderate relationship between high sensation-seeking and MAO level levels (Zuckerman, 1991). Cloninger’s model also accounts for a risk-taking personality type and calls it novelty seeking (1987). Cloninger explains this behavior in terms of low dopamine levels. The resulting behavior is an attempt to activate the brain’s reward system and increase dopamine levels. Finally, Gray accounts for risk-taking behavior in terms of the relative balance of two brain-based systems. An individual who engages in risk-taking behavior is overly sensitive to the rewards associated with the behavior (the
result of BAS activity) and insensitive to the potential consequences (resulting from a lack of BIS activity). In addition, Gray’s BAS and BIS both are hypothesized to involve several neural areas and pathways.

In examining the relations among these four theories (Eysenck, Zuckerman, Cloninger and Gray), it appears that they are fairly consistent with each other regarding personality traits related to risk-taking behavior. The main disagreements seem to be regarding the physiological origin of such traits. Gray’s theory may be useful as a way to unify the theories and provide a conceptual biological model. It seems plausible that these traits are the manifestations of relative differences between BIS/BAS functioning. Individual differences, therefore, can be explained in terms of the balance between BIS/BAS functioning. The next step would be to generate and test hypotheses based on this individual difference model. In the present study, therefore, a measure of Gray’s BIS/BAS concept was utilized to explore the role of disposition in the decision-making process.

Affect and Decision-Making

Another important component to understanding risk-taking behavior is decision-making. It was once commonly believed that if an individual knows there are negative consequences to engaging in a particular behavior, then the individual will make the rational choice and make the decision to not engage in the risky behavior. This rationality based view was once generally accepted and goes as far back as Plato, who argued that people engage in bad activities simply because they did not know they were bad (Flew,
Again, it is worth noting the prevalence and variety of risk-taking behaviors that individuals engage in. It is also worth noting that negative consequences of many risky behaviors are known to the general public (i.e., drug use, smoking, unsafe sex). Despite this knowledge, individuals continue to take part in these behaviors.

The Affective Heuristic

The inadequacy of a rationality-based model of decision-making led to the introduction of affective based factors as potentially important dimensions in decision-making (Shafir & LeBoeuf, 2002). Research has shown that moods can influence choice and judgments regarding perceived frequency of risk (Johnson & Tversky, 1983). Affective models state that mental images are marked by positive or negative feelings. These images guide decisions and they require less time and effort than traditionally conceptualized decision-making processes. Some researchers have called this component of decision-making an “affective heuristic” (Finucane et al., 2000). Some researchers have theorized that anticipatory affective arousal influences cognitive appraisals of novel stimuli and compete with the cognitive system in fostering a response (Lowenstein et al., 2001).

The affective heuristic refers to the theory that representations of objects and events in an individual’s consciousness are associated with varying degrees of affect. When making judgments, an individual will consult with positive and negative associations (consciously or unconsciously). This process may be a more efficient way of making a decision than weighing the positive and negative potential outcomes or retrieving from memory all the relevant examples. Decision-making researchers have used the affect heuristic to explain the inverse relationship between perceived risk and
perceived benefit. For example, for many hazards, the greater the perceived benefit, the lower the perceived risk and the same inverse relationship exists when the risk is greater (the benefit is lower; McDaniels, Axlerod, Cavanagh & Slovic, 1997). Alhakami & Slovic (1994) observed that the relationship between perceived risk and benefit was connected to the individual’s affective evaluation of the hazard. Activities that were liked were judged as less risky and more beneficial, and activities that were disliked were judged as higher in risk and of low benefit.

A study by Finucane, Alhakami, Slovic & Johnson examined the affect heuristic in judgments of risks and benefits (2000). Finucane et al. attempted to rule out a cognitive explanation of the inverse risk/benefit relationship with the use of time pressure. Since using the affect heuristic is theorized to be more efficient, it was hypothesized that individuals in a time pressure condition would rely more heavily on affect when making judgments regarding risks and benefits. As a result, the negative correlations between risk and benefit judgments were expected to be stronger for individuals in the time pressure than the no time pressure condition. This study included 54 undergraduate students (mean age 19, 78% female). Participants were randomly assigned to one of two conditions (time pressure or no time pressure). Participants rated activities and technologies on a 7-point scale ranging from not at all risky (or beneficial) to very risky (or beneficial). In the time pressure condition, after a 5.2 second period, a yellow sign flash indicated that a decision must be made and the computer beeped until a rating was made for the item.

Results indicated that participants in the time pressure condition took significantly less time to do the risk judgments than the participants in the no time pressure condition.
Correlations between judged risk and judged benefit for individuals rating across 21 items (two items were removed because of extreme ratings) indicated correlations of –0.69 for time pressure, and –0.62 for no time pressure. Correlations on each participant’s ratings across the 21 items showed a similar pattern. For the time pressure condition, the mean correlation was –0.45. For the no time pressure condition, the mean correlation was –0.33. The difference between these mean correlations approached significance ($p = 0.05$). When examining correlations for individual items between the two conditions, eight were significantly different at the 0.01 level, and five were significantly different at the 0.05 level for the time pressure condition, but only two items were significant for the no time pressure condition. This study provides evidence for the author’s main hypothesis and also provides evidence for the affect heuristic as a particularly important mechanism when efficient and quick judgments are necessary.

*The Framing Effect*

Another widely studied phenomenon in decision-making research is the framing effect. The framing effect was first introduced by Tversky and Kahneman (1981) and is considered an integral part of the initial phase of many decision situations. Framing was described as a cognitive operation that acts upon the components of the choice alternatives (outcomes and probabilities; Tversky & Kahneman, 1981). The concept of framing arose from limitations of rational theories of decision-making to explain the systematic violations of the requirements of consistency and coherence that would be satisfied by rational choices (Tversky & Kahneman, 1981). Instead, the idea of a “decision frame” was utilized to refer to the components that are involved in an individual’s decision. These components include the outcomes and contingencies
associated with a particular choice. A decision-maker will adopt a frame that is controlled by the norms, habits and personal characteristics of that decision-maker as well as the formulation of the problem (Tversky & Kahneman, 1981). Theorists have begun to suggest that framing influences decisions because it may have a strong affective influence on the decision-maker’s anticipation of the outcome resulting from his or her decision (Frisch, 1993). Empirical studies have supported this notion. Studies have shown that both positive and negative mood states have a strong influence over likelihood estimations and actual decision-making under risk or uncertainty. For example, individuals in a negative mood make significant overestimations of likelihoods of negative events and underestimations of positive events, and those in a positive mood do the opposite (Wright & Bower, 1992). In actual gambling situations, mood has been shown to have a significant influence on the choices that are made. Studies have shown that individuals in whom positive affect has been induced tend to be more conservative or self-protective in situations where there is a focus on meaningful loss or where loss is highly likely (Arkes, Herren, & Isen, 1988). In gambling situation, positive affect seems to increase aversion to choosing riskier options, but exhibits little or no effect on anticipation of positive gains (Nygren, 1998). Negative affect has been studied less and its effects are less understood than those of positive affect.

Two studies by Nygren (1998) investigated the relationship between affect and framing in a risky decision-making task (gambling game). In the first study, participants were assigned to one of four conditions in a 2 (Affect: Positive vs. Negative) X 2 (Risk Level: Low vs. High). Affect was manipulated by presenting participants in the positive affect group with a blank audiotape as a token of the researcher’s appreciation.
Participants also rated themselves on 50 mood induction statements that included 40 positive items for the positive affect group and 40 negative items for the negative affect group. The findings were consistent with predictions based on the literature in that positive affect participants were consistently more risk averse in their gambling behavior than were negative affect participants in a high-risk environment. Positive affect participants were more risk accepting in a low-risk environment. The second study used the same procedure as the first study with one modification. Participants were assigned to high-risk or low-risk gambling situations, but then were split into either a positive winning frame or negative losing frame condition. For the positive winning frame, instructions for the task were presented in a positive way (e.g. make judgments based on probability of winning). For the negative losing frame, instructions were presented in a negative way and participants were asked to think about and make their judgments in terms of probabilities of losing. The results of the framing manipulation were consistent with that of the affect manipulation in the first experiment. In a high-risk situation, where real loss is possible, participants in a winning frame are more risk averse relative to losing frame participants. Nygren (1998) concludes that there is a clear similarity and theoretical link between the effects of framing and the effects of affect manipulation.

Nygren offers some possible explanations for the framing and affect link, focusing on the idea of mood management motives and the fact that they are more likely to function in positive mood states (Carlson, Charlin, & Miller, 1988). Motivations based on mood management suggests that in a high threat of loss situation, positive framing-induced mood can best be maintained if a “rational” response strategy is formulated that will minimize losses to such an extent that an overt risk-averse decision strategy is
adopted. This strategy would maintain positive position relative to a reference point and completely avoids situations where large potential losses are perceived as possible, regardless of what might be gained (Nygren, 1998). On the other hand, a negative mood might best be neutralized by anticipation of possible future gains. Positive feelings may be fostered by overweighing utilities of imagined or anticipated future gains to such an extent that a decision strategy with a moderate level of risk is employed (Nygren, 1998).

*The Role of the Frontal Lobes*

Other lines of research have focused on the theory that good decision-making requires the use of affect, and that the absence of affect in the decision process leads to decision-making deficits. The work of Damasio and colleagues has focused on these factors using neurologically impaired patients, especially those with damage to the frontal lobes. Since Phineus Gage had an iron bar thrust through his skull, resulting in damage to the frontal lobes, an association has been made between emotion and this area. After his accident Gage recovered, but with great personality changes such that his friends said he was “no longer Gage” (Harlow, 1868). Damage to the prefrontal cortex is associated with behavior and personality change, problems with judgment, foresight, and social principles. As with Phineas Gage, patients with damage to this area demonstrate extremely poor decision-making. Often faulty decision-making is most apparent in the social domain, where inappropriate behavior is often exhibited. Despite real-world decision-making deficits, these patients often show no problems with regard to intellect or other basic cognitive skills (Damasio, 1994). As a result, their deficits cannot be explained by problems related to general intelligence, impaired expression or comprehension, working memory, or attention (Bechara, Tranel, & Damasio, 2000).
Studies of these patients have led Damasio to develop the somatic marker hypothesis (1994) to explain the neural basis of decision-making in terms of the development of affective responsive that are processed in the prefrontal lobes.

Neurobiology and Decision-Making: The Somatic Marker Hypothesis

To explore the neurobiological substrates of decision-making, it makes sense to start with the frontal lobes. The frontal lobes are associated with the executive functions that are higher-level cognitive functions involved in the control and direction of lower-level functions (Stuss & Levine, 2002). Stuss and Benson (1986) have proposed that the frontal lobes act at three levels. First, they maintain and organize sensory information, stored in sensory-bound cognitive systems, into meaningful behavioral sequences that initiate behaviors. Second, they exert executive control on behavior through monitoring and evaluating outcomes. Third, they are responsible for awareness of self, self to environment, and past and future. Ultimately, the prefrontal cortex is the area where all information about stimuli converges and is evaluated.

The role of the prefrontal cortex in reward has been well documented in both human and nonhuman research (Rolls, 2000). Monkeys with prefrontal lesions are impaired in tasks that involve learning which stimuli are rewarding and which are not. Monkeys with prefrontal damage have been shown to be impaired in go/no-go tasks (Iverson & Mishkin, 1970), in object reversal tasks (they continue to respond to objects formerly rewarded with food), and in extinction (Jones & Mishkin, 1972). In a visual discrimination reversal task that required individuals to learn to obtain points by touching
one stimulus on a video monitor and withholding a response when another stimuli was presented and then reversing the reinforcement contingencies unexpectedly, patients with orbitofrontal damage performed significantly worse than normal controls and patients with brain damage to other parts of the frontal lobes (Rolls, Hornack, Wade & McGrath, 1994). The individuals were not impaired in other types of tasks involving paired association learning. Also of interest in this study was that the impairment correlated with socially inappropriate and disinhibited behavior of the patients. Research into the prefrontal lobe suggests that this area has important functions in motivational behavior, emotion and social behavior, and stimulus-reinforcer association learning (Rolls, 2000).

Developmentally, the prefrontal lobes, although present in childhood, are slower to mature than any other brain structure (Spreen, Risser, & Edgell, 1995). In particular, the prefrontal lobes are not fully mature until young adulthood, whereas posterior areas mature by middle childhood (Segalowitz & Rose-Krasnor, 1992). Research suggests that children age 12 and under do not perform at adult levels on tasks believed to require intact functioning of the prefrontal cortex. For example, 11 to 12-year-olds have been shown to perform at sub-adult levels on measures of working memory, planning, verbal fluency, and motor sequencing (Luciana & Nelson, 2002; Welsh, Pennington & Groisser, 1991). Imaging studies have supported the notion of continued maturation of brain function, with the prefrontal cortex not fully maturing until late adolescence or early adulthood (Nelson & Luciana, 2001; Pennington, 1998).

The orbital prefrontal cortex’s link to decision-making in normal adults was demonstrated in a study by Rogers, Owen, Middleton, Williams, Pickard, Sahakian and Robbins (1999). Eight right-handed, healthy male volunteers took part in this study. The
mean estimated verbal IQ of the participants (as estimated with the National Adult Reading test) was 120.9. Mean age of the sample was 31.9. The participants underwent 12 positron emission tomography (PET) scans and one magnetic resonance imaging scan within a single session. Participant completed a decision-making task and a control condition. When comparing activation during the decision-making (risk task) versus the control condition, the authors found isolated and significant activation in the ventral sectors of the right prefrontal cortex (Rodgers et al., 1999).

*The Somatic Marker Hypothesis*

Damasio et al. (1994) suggest that emotions are essential for guiding and driving prefrontal behavior functions. Emotions would ensure the appropriateness to situational and social aspects of behaviors that are based on rational reasoning and logical premises. This idea fits nicely with the suggestion that information from the external environment, gathered through all systems, converges in the frontal lobe (Fuster, 1996). As a result, predicting consequences of a behavior, or choosing an alternative action, is a frontal lobe function. This brings to question the neuropsychological aspects of decision-making and what the role of emotion is to decision-making. As mentioned earlier, patients with damage to the prefrontal cortex demonstrate extremely poor decision-making, but their intellect remains intact. The work of Damasio and Bechara has resulted in a hypothesis regarding the role of affect in decision-making and connected it to a specific brain region.

The somatic marker hypothesis is based on the belief that when presented with a decision, before any cost/benefit analysis or reasoning towards a solution occurs, any bad outcomes connected with a particular option are accompanied with an unpleasant physical feeling (Damasio, 1994). The negative feeling is the somatic marker and its
purpose is to draw attention to the negative outcome of a particular decision. Since the somatic marker occurs before the reasoning and cost/benefit analysis aspects of decision-making, no deliberation is involved. Instead, somatic markers simply highlight and red flag certain options. The somatic markers are learned through experience and are acquired with regard to social conventions and rules, external circumstances, and internal preferences.

The prefrontal cortex is the major system responsible for the acquisition of somatic marker signaling (Damasio, 1994). The prefrontal cortex receives input directly and indirectly from all sensory modalities. There are also bi-directional connections with the amygdala. Bi-directional connections also exist with the somatosensory and insular cortices. Bechara et al. (2000) describe what occurs neuroanatomically when a person is faced with a decision and the ventromedial prefrontal cortex is activated. There are two physiologically based chains of events that may occur, either separately or together. In the first chain, an appropriate emotional state is re-enacted, and signals from this activation are relayed to cortical and subcortical somatosensory procession areas. In this chain, the signal travels from the prefrontal cortex, then goes to the amygdala, then the body, then travels up from the body through the brain stem, and then to the somatosensory/insular cortices. This system is called the “body loop” and is demonstrated in Figure 2.

The second chain occurs after emotions have been expressed and experienced at least once prior and representations of these emotional experiences have been formed in the somatosensory processing structures. As a result, the body is bypassed and the somatosensory/insular cortices are activated directly. The resulting emotional body state
is not as strong as if it were experienced in the body. This is called the “as if body loop” and is demonstrated in Figure 3.

*Figure 2. The Body Loop*

*Note. PFC= prefrontal cortex; AM= amygdala; SIC= somatosensory/insular cortices*

*Figure 3. The “As If” Loop*

*Note. PFC= prefrontal cortex; AM= amygdala; SIC= somatosensory/insular cortices*

These somatic states are a direct result of learning. It is theorized that strategies for making a decision rely on the symbols of somatic states called somatic markers.
Damasio’s theory can be conceptualized as a more sophisticated version of Gray’s theory of behavioral activation and behavioral inhibition systems. According to Gray, when a person is faced with a decision that is associated with reward, the BAS is activated and the person will decide to approach. If the decision is associated with punishment, the BIS is activated and the person will not approach. The activation of BIS and BAS is the result of prior experiences of the stimuli and the resulting outcomes.

The end result of these processes is that the outcomes of a decision are marked with affective content. This leads to hypothetical choices with possible bad outcomes being marked with negative affective content and good or beneficial outcomes with positive affective content. This information is then brought into the decision-making process in several ways. First, the information serves to eliminate choices with bad outcomes and biases judgment towards outcomes that are positive or beneficial to the person. Since situations involving social matters and personal relationships and other personal matters are loaded with an abundance of emotion, it can be inferred that somatic markers are of great importance with regard to decisions in these areas.

The Gambling Task

Evidence for the somatic marker hypothesis comes from the use of the Gambling Task (Bechara, Damasio, Damasio & Anderson, 1994). The Gambling Task consists of four decks of cards (labeled A, B, C, D) and requires the subject to make a long series of card selections. Subjects are given a $2000 loan of play money and told to pick one card at a time from any of the four decks. After turning a card, the subject is given money and sometimes also asked to pay a penalty. The amount of payment and penalty is announced after the card selection and varies with regard to the deck and position in the deck. Decks
A and B offer higher immediate payoff than decks C and D; however, decks A and B have higher penalties than decks C and D. To maximize profits, the subject must choose from decks C and D. Subjects have no knowledge of the payment schedule. Subjects are told that the goal of the task is to maximize the profit on the loan money and that they are free to choose from any deck and switch between decks at any time.

Research on the Gambling Task with patients who have damage to the prefrontal cortex has found that many of them who have preserved intellect and no other neuropsychological deficits perform poorly on this task. These individuals often have severe social deficits and cannot function independently, despite retaining normal intellectual abilities. They show a preference for the bad decks (A and B) while normal controls show a preference for the good decks (C and D) (Bechara et al., 1994). The conclusion of studies using the Gambling Task is that patients with damage to the prefrontal cortex are insensitive to future consequences.

In order to better understand why individuals with prefrontal lesions performed poorly on the Gambling Task, Bechara and colleagues (1996) measured the skin conductance responses (SCRs) of subjects while they performed the Gambling Task. This study consisted of both normal subjects and subjects with damage to the ventromedial prefrontal cortex. Both groups of subjects generated SCRs after picking a card and being told they won or lost money. As normal subjects became experienced with the task, SCRs began to occur prior to card selection. The anticipatory SCRs were more pronounced for selections from the bad decks (A and B) than from the good decks (C and D). The anticipatory responses are operationally defined as the SCR generated five seconds after the selection of the previous card until the selection of the next card. These anticipatory
responses serve as somatic markers that warn the subject about the outcome of the selection from the bad decks. In contrast, the subjects with ventromedial prefrontal cortex damage did not generate these anticipatory responses to the bad decks. This is believed to support the idea that emotional signals guide decision-making by generating anticipatory “gut feelings” that guide subjects towards advantageous decisions (Bechara et al., 1996). Further studies also reveal that the somatic markers need not be consciously perceived (Bechara et al., 1997). Individuals who have taken part in the Gambling Task and have shown anticipatory SCRs to the disadvantageous decks, often report not having an explanation as to why they begin choosing from the advantageous decks, and report not having any intuition about which decks are good or bad. The anticipatory SCRs exhibited by normal controls on the Gambling Task begin to appear on trials 10 through 20. The discrepancy between anticipatory SCRs to disadvantageous decks and anticipatory SCRs to advantageous decks reaches its greatest magnitude at around trial 60 on the Gambling Task (Bechara, Damasio, Damasio & Lee, 1999; Bechara & Damasio, 2002). Bechara and colleagues have consistently concluded from their research that the main deficit in subjects with ventromedial prefrontal lesion is insensitivity to future consequences. Researchers from a biological trait perspective (e.g., Cloninger, Zuckerman and Gray) may argue that the deficits observed on the Gambling Task represent either a hypersensitivity to reward or insensitivity to punishment. A study by Bechara, Tranel and Damasio (2000) examined performance on a variant of the Gambling Task with ventromedial prefrontal cortex lesions and a control group. The variant of the Gambling Task consisted of the advantageous decks yielding high immediate punishment and even higher future reward. The disadvantageous decks yielded low immediate punishment and
even lower future reward. Results indicated that patients with prefrontal lesions preferred 1) decks with high immediate reward, although decks with small reward were more advantageous in the long run, and 2) decks with low immediate punishment, although decks with higher immediate punishment were more advantageous in the long run. Controls displayed the opposite preferences: small immediate reward and more advantageous in the long run, and high immediate punishment and more advantageous in the long run. In addition, patients with lesions generated SCRs after reward and punishment that were not significantly different from controls.

Bechara et al. (2000) concluded that this study provides evidence against the decision- making deficit on the Gambling Task resulting from hypersensitivity to reward or insensitivity to punishment. The pattern of results indicated that patients with prefrontal lesions were not lured by high rewards, as would be expected if they were hypersensitive to reward, and they stayed away from decks with large immediate penalties which is inconsistent with insensitivity to punishment. Overall, what these individuals exhibited was insensitivity to future consequences, whether those consequences are positive or negative.

Another argument arising from the behavior of patients with lesions to the prefrontal cortex is whether their behavior can be interpreted in terms of impulsivity. Impulsivity has been linked to dysfunction of the prefrontal cortex (Miller, 1992). Impulsivity can be broadly distinguished into two kinds: motor and cognitive. Motor impulsiveness involves making responses before all necessary information has been obtained and taking quick action without thinking, whereas cognitive impulsiveness is similar to an inability to delay gratification (Bechara et al., 2000). Bechara et al. (2000)
report that the prefrontal lesion patients they have used in their research did not suffer from motor impulsiveness. It is also argued that perseveration is an indication of impulsivity (Evenden, 1999). It has been noted that patients with lesions to the dorsolateral sector of the prefrontal cortex exhibit impaired performance on the Wisconsin Card Sorting Test. These individuals often will continue with a classification category of cards despite being told it is wrong (Bechera et al., 2000). Although it has been suggested that perseveration on the WCST is an example of impulse control, perseveration does not predict the behavior of patients with lesions to the ventromedial prefrontal cortex since these patients are not typically impaired on the WCST (Anderson, Damasio, Jones & Tranel, 1991).

Cognitive impulsiveness is more akin to what is observed in patients with ventromedial lesions (Bechera et al., 2000). These patients are unable to delay the gratification of the reward. When presented with a deck of cards with a large immediate reward but delayed costs, they seek the reward. Bechera and colleagues argue that the nature of the mechanism a person uses to decide whether to suppress or not suppress a certain response is a somatic state (2000).

The use of the Gambling Task has led to a theory that associates an individual’s decision-making ability to the ventromedial prefrontal cortex. This decision-making capacity is hypothesized to be independent from the individual’s other cognitive abilities. Subjects with prefrontal damage often display intact intellectual ability, yet are unable to make real life decisions that are advantageous to them. During the Gambling Task, these subjects are unable to delay gratification, and instead make decisions that provide a greater instant reward but lead to greater losses in the long run. These findings are
consistent with the real-world problems faced by these individuals. Furthermore, the
Gambling Task provides evidence for affective information having a central role in the
cognitive system during decision-making.

Some criticism has been directed at research with the Gambling Task. Manes,
Sahakian, Clark, Rogers, Antoun, Aitken, and Robbins (2002) point out that the research
by Bechara and colleagues has been with participants who have damage including the
orbitofrontal cortex and not restricted to this area. Also, there are potential confounding
effects of psychiatric symptoms. This may be particularly relevant to mood disorders
since, as discussed earlier, affect can influence the decision-making process (Frisch,
1993). Since secondary mood disturbance is documented following frontal cortex damage
(Robinson Boston, Starkstein & Price, 1988), this may influence the decision-making
process independently of the organic damage. A study by Manes et al. (2002) explored
impaired decision-making in participants with damage to different parts of the prefrontal
cortex. Participants were selected from a database of volunteers with focal brain lesions.
Of the 19 participants included, 18 had MRI scans with T1-weighted sequence and a T2-
weighted axial sequence. One participant had his lesion location determined from a
previous MRI scan. Four groups were identified: discrete orbitofrontal lesions (n = 5),
discrete dorsolateral lesions (n = 4), discrete dorsomedial lesions (n = 5), and lesions
involving ventral and dorsal areas of the prefrontal cortex (large lesion group; n = 5). In
addition, 13 healthy controls were recruited through ads in the local newspaper. Current
or previous psychiatric diagnosis were exclusion criteria in this study.

Participants completed a variety of neuropsychological tests, including verbal and
category fluency, spatial span (visuospatial short-term memory test), pattern/spatial
recognition memory (pattern recognition task), spatial working memory, one touch Tower of London (a variant of the original that requires participants to view two arrangements of colored balls and calculate how to move the balls in one arrangement to form the second arrangement), and three dimensional attentional set shifting (participants discriminate stimuli based on color, shape, or number of components; participants must stay with the correct dimension while new stimuli are introduced in the intra-dimension shift stage, and participants must shift responding to new dimension in the extra-dimension shift stage). In addition, the participants completed the standard Gambling Task as well as the “gamble” task (Rogers, Everitt, Baldacchino, Blackshaw, Swainson & Wynne, 1999). The “gamble” task presents participants with a display of a mixture of red and blue boxes and they must decide whether they think a yellow token is hidden under a red or blue box. The ratio of red to blue boxes varies from trial to trial in a randomized manner. The probability of the participant choosing correctly is independent on each trial. After participants choose blue or red, they place a bet on their confidence in their decision being correct. This task separates the probabilistic element of decision-making from the risk-taking element since choice and response are separate. Participants also completed the “risk task” (Rogers, Andrews, Grasby, Brooks, & Robbins, 1999). This task is a variant of the “gamble task” except with a fixed bet with each choice of box color. The magnitude of bets is determined by the likely outcome; for example, a ratio of five blue boxes to one red box would be accompanied by a gamble of 10 points for choosing blue and 90 points for choosing red.

On the Gambling Task, the combined frontal group made significantly more selections from risky decks than controls, and there was a significant effect across the
five subgroups. Three subgroups were impaired compared to controls: the dorsolateral group, the dorsomedial group, and the large lesion group. The performance of the orbitofrontal group was similar to controls. On the “gamble task” there was no significant difference for the combined group compared to controls, and there were no significant differences between the five subgroups for quality of decision-making. On the “risk task,” the large lesion group chose the likely outcome significantly less than controls in the 5:1 ratio. For the 4:2 ratio, the combined frontal group chose the likely outcome less often than controls, but there were no difference among subgroups.

The findings of Manes et al. (2002) raise some questions regarding the link between orbitofrontal damage and impaired decision-making. Individuals with specific lesions to the orbitofrontal cortex were not impaired in any of the decision-making tasks, contradictory to previous research (Bechara et al., 1994). Also, patients in Bechara’s studies had lesions that would have placed them in the large lesion group in the study by Manes et al. The large lesion group did display decision-making impairment on the Gambling Task. In addition, there may be some relationship between laterality of lesion to the orbitofrontal cortex and decision-making. For example, Bechara’s patients had bilateral lesions, whereas four out of the five participants in the Manes et al. study had left–sided lesions to the orbitofrontal cortex. The Manes et al. study also excluded participants with current or previous psychiatric diagnosis. Manes et al. also point out that although dorsolateral and dorsomedial patients were impaired on the Gambling Task, dorsolateral patients were impaired on the working memory test, and dorsomedial patients were impaired on the Tower of London task. This suggests that Gambling Task
performance could be explained in terms of other neuropsychological impairments and not just decision-making.

In terms of explaining the results of Manes et al. (2002), several points need to be considered. Probably the most important is that the participants in their orbitofrontal group did not display the same kind of real life decision-making deficits as did those in Bechara’s study. As mentioned earlier, Bechara’s patients had bilateral lesions, whereas in the study by Manes et al., the majority of patients had left-sided orbitofrontal lesions. A PET imaging study by Rogers et al (1999), using healthy participants, demonstrated predominantly right-sided orbitofrontal cortex activation associated with a risk-taking task. In addition, an abstract by Tranel, Bechara, Damasio and Damasio demonstrated that patients with right, but not left, ventromedial prefrontal cortex damage were impaired on the Gambling Task (2000, as cited in Manes et al., 2002). Manes et al. also excluded individuals with current or previous psychiatric diagnosis. If affect is related to Gambling Task performance, then their results might reflect the fact that individuals experiencing significant negative affect were not included in their sample. This could have resulted in a subset of individuals with better performance due to less negative affect. The Manes et al. study still raises some question about the relationship between prefrontal cortex damage and decision-making, and more research is required, preferably comparing specific lesions of the right and left orbitofrontal cortex, to better understand their results.

Research with the Gambling Task originally focused on neurologically impaired individuals who demonstrated real life decision-making deficits. Taken as a whole, this research implicates the ventromedial prefrontal cortex as a major component in decision-making. Developmentally based studies have had results consistent with the general
findings that the prefrontal lobes do not fully mature until early adulthood. However, this research does not necessarily generalize to neurologically intact adults who engage in risk-taking activities. Exploring normal variation in Gambling Task performance may shed light on risk-taking behavior in the general population. This adds another component to the existing literature on risk-taking behavior and may allow for the study of dispositional variables related to risk-taking from another, and more objective, perspective.

Gambling Task Performance in Clinical and Sub-Clinical Populations

As noted earlier, the change in an individual’s decision-making behavior after damage to the prefrontal cortex is well documented. Research using the Gambling Task has shed some light onto the nature of the decision-making deficit that is central to the behavior exhibited by these patients. But some intriguing research suggests that the pattern extends into individuals without clear evidence of neurological damage as well. This raises the question of whether this model can explain risk-taking behavior in individuals with risk-related psychological diagnoses but without clear damage to the prefrontal lobes.

Schmitt, Brinkley and Newman (1999) examined Gambling Task performance on a group of psychopathic individuals. The study involved 157 incarcerated men from a minimum-security prison. Participants were evaluated using the Psychopathy Checklist–Revised. Participants with a score of 20 and below were classified as controls (n = 29 for Caucasian, n = 22 for African Americans), participants with a score between 20 and 30 were classified as middles (n = 38 for Caucasians, n = 30 for African Americans), and participants with scores of 30 and above were classified as psychopathic (n = 19 for...
In addition, participants completed the Welsh Anxiety Scale and were classified into low and high anxiety groups based on a median split for the entire group. The Gambling Task was broken down into five blocks of 20 trials and a three (control vs. middle vs. psychopath) X two (high vs. low anxiety) X five (block of 20 trials) ANOVA was conducted. No main effect was found for psychopathy and Gambling Task performance in the Caucasian or African American groups. However, a main effect was found for anxiety and anxiety X block for the Caucasian group. High anxious participants became more risk averse over time compared to low anxious individuals. No significant effects were found for the African American group.

In order to examine the effects of treating the psychopathy and anxiety variables continuously, a post-hoc hierarchical regression was conducted. Number of risky selections on the last half of the Gambling Task (trials 51-100) was the criterion variable and the predictors were psychopathy, anxiety and their interaction. For the Caucasian group, anxiety and the anxiety-psychopathy interaction accounted for a significant amount of the variance. For the African American group, only anxiety accounted for a significant amount of the variance. The significant relationship between risk taking and anxiety in the African American group was in the opposite direction of the association in the Caucasian group; that is, anxiety was positively related to number risky selections. Several aspects of this study need further analysis. The lack of a main effect of psychopathy may be attributable to the populations used. Their results are consistent with more recent research that has failed to find a significant relationship between psychopathy and Gambling Task performance in incarcerated men (Losel & Schmucker, 2004). As the authors point out, their control group may not have been as risk averse as
controls in other studies using the Gambling Task. In fact, given that these individuals are incarcerated as a result of engaging in illegal behavior, it can be argued that they are low with regard to risk aversion. Also, the unusual direction of the relationship between anxiety and Gambling Task performance in the African American group may be the result of the anxiety measure utilized in this study reflecting different processes for Caucasians and African Americans. It has been noted that anxiety can disrupt information processing in a variety of ways (Watson, Clark, & Tellegen, 1988) and the authors point to reports of paradoxical impulsivity in high anxious individuals (Newman & Wallace, 1993). As a result, no firm conclusions can be made regarding this finding and further research into this phenomenon is warranted. Finally, the expected effect of anxiety on Gambling Task performance in the Caucasian group has one important implication. It appears to provide evidence for models of risk aversion based on individual differences. In particular, it is consistent with what would be predicted by Gray’s model. In this model, a high anxious individual would be punishment sensitive and adapt very quickly to the Gambling Task. Furthermore, once they avoid big losses, they would stick to that strategy and take fewer chances, so they would be less likely to sample from the potentially dangerous choices. This appears to be what happened with the high anxious individuals in this study.

Substance dependent individuals engage in risk-taking behavior similar to that of patients with prefrontal cortex lesions in that their decisions seem guided by immediate reward despite the serious negative consequences associated with their behavior (i.e., loss of job, financial trouble, and legal problems). Research with drug abusers has revealed that they perform worse on the Gambling Task than do normal individuals. Grant,
Contoreggi & London (2000) administered the Gambling Task to 30 polysubstance abusers and 20 controls. All participants were given a structured psychiatric evaluation and were excluded if they had a history of head trauma or lifetime Axis I psychiatric diagnosis other than a substance abuse disorder. The results indicated that substance abusers performed significantly worse than controls on the Gambling Task. On the Wisconsin Card Sorting Test (WCST) there were no significant differences between groups on seven variables examined (categories completed, total errors, perseverative errors, non-perseverative errors, trials to first category, and failure to maintain set).

Bechara and Damasio (2002) examined the performance of substance dependent individuals on the Gambling Task as well as other measures of executive functioning. Substance dependant individuals were selected from a drug rehabilitation treatment center and the SCID-IV was used to assign an Axis I substance dependence diagnosis. This study involved 46 substance dependent individuals, 10 patients with lesions to the ventromedial prefrontal cortex, and 49 normal individuals. No differences between groups were found for intelligence (as measured by the WAIS-III), the Benton Visual Retention Test (a measure of visual perception, visual memory, and visual-constructive abilities), immediate and delayed verbal memory (the Rey Auditory Verbal Learning Test), the Stroop Color Word Test, and the Tower of Hanoi (two measures of executive functioning). On the Gambling Task, the normal group performed significantly better than both the substance dependent group as well as the prefrontal lesion group. In addition, the substance dependent group performed better than the prefrontal lesion group. Consistent with the somatic marker hypothesis, analysis of SCRs indicated that normal controls had significantly higher anticipatory SCRs than substance dependent
individuals for disadvantageous decks. For both advantageous and disadvantageous decks, both normal controls and substance dependent individuals had significantly higher SCRs. Substance dependent individuals also had more perseverative errors on the Wisconsin Card Sorting Test (WCST) than either normal controls or patients with prefrontal lesions. Further analyses revealed that the substance dependent group could be split into two subgroups. One subgroup was indistinguishable from normal controls on both Gambling Task performance and SCR data; the other subgroup displayed both impaired Gambling Task performance and impaired anticipatory SCRs that resembled prefrontal patients (Bechara & Damasio, 2001). There were no differences between substance dependent individuals impaired on the Gambling Task and substance dependent individuals unimpaired on the Gambling Task on any cognitive measures.

This study also examined the acquisition of a conditioned SCR in response to a loud noise in order to examine whether substance dependent individuals’ impairment was consistent with prefrontal or amygdala dysfunction. Prior studies compared patients with prefrontal lesions and amygdala damage in a Pavlovian conditioning experiment (Bechara, Damasio, Damasio & Lee, 1999). This experiment used four color slides (blue, red, green, orange), with blue as the conditioned stimulus, a loud noise (fog horn) as the unconditioned stimulus, and SCR as the dependent measure of autonomic conditioning. Results indicated that while both prefrontal lesion patients and patients with amygdala damage performed poorly on the Gambling Task and demonstrated impaired acquisition of anticipatory SCRs with regards to disadvantageous selections, prefrontal patients and normal controls showed conditioned SCRs in the Pavlovian conditioning experiment. However, patients with amygdala damage failed to show conditioned SCRs (Bechara et
al., 1999). Substance dependent individuals also show conditioned SCRs in this paradigm consistent with normal controls and prefrontal lesion patients (Bechara & Damasio, 2002).

Another study with substance dependent individuals on the Gambling Task used the variant version described earlier to examine whether their poor performance on the original Gambling Task was better accounted for by hypersensitivity to reward or insensitivity to future consequences (Bechara, Dolan, & Hindes, 2002). This study revealed three subgroups of substance dependent individuals. One group performed normally on the Gambling Task. Of the subjects who performed poorly, 36% showed similar behavioral and physiological impairments to prefrontal patients. The other subgroup (64%) performed normally on the variant Gambling Task but had abnormally large physiological responses post reward and in anticipation of choices that lead to a large reward. The authors concluded that in a large subgroup of substance dependent individuals, there is a hypersensitivity to reward where the presence of, or possibility of receiving, a reward is the main factor in controlling choice and behavior (Bechara et al., 2002).

The results of these studies suggest that the type of risk-taking behavior demonstrated by substance dependent individuals (i.e., continued drug use despite consequences) can be explained by two types of abnormalities in the prefrontal cortex system (Bechara et al., 2002). The first abnormality is consistent with that of patients with lesions to the ventromedial prefrontal cortex. The second abnormality may reflect a hypoactive amygdala for processing punishment. As a result, when presented with decisions involving future punishment, the anticipation of punishment is weak since the
representation of the somatic state of punishment was weak in the insular cortex. Ultimately, choices with future punishment are not avoided as a result of reduced anticipatory somatic states for negative outcomes associated with those choices.

Increased reward SCRs in substance dependent individuals can be explained in terms of a hyperactive amygdala. This hyperactivity results in stronger representation of the feeling state of reward in the insular cortex. In this case, anticipating or thinking about reward leads to a stronger somatic state for reward. Again, it is worth noting the consistency between this finding and Gray’s theory. In Gray’s model, substance dependant individuals can be labeled as BAS driven in that they have strong conditioned stimuli for reward. Furthermore, the hypoactive amygdala for processing punishment results in a weak BIS, allowing the BAS to drive the behavior.

Developmental Aspects of Gambling Task Performance

Developmental research using the Gambling Task has been consistent with prior research that has generally found continued prefrontal lobe development into early adulthood. Crone and van der Molen (2004) used a developmentally appropriate variant of the Gambling Task (the hungry donkey task) that retained the basic format of the original. This task required participants to open doors to find apples to feed the hungry donkey. There are four doors with two being disadvantageous and two being disadvantageous with a reward and loss schedule, over 100 trials, consistent with the original Gambling Task. Their participants made up four different age groups: 6-9, 10-12, 13-15, and 18-25. Results indicated that 18 to 25-year-olds performed significantly better than the other three groups and the 13 to 15-year-olds performed better than the two younger groups. Analysis of the patterns of performance revealed that adults made
advantageous selections early during the task and children developed the preference for advantageous selections later in the task, if at all. Also, adults made significantly more advantageous selections beginning in the third block of trials (trials 40-60), whereas in the adolescent group, the shift in preference occurred at the fifth trial block (trials 80-100). To rule out reward sensitivity, participants also completed a reversed version of the task. On this version, opening doors results in the loss of apples with occasional rewards. Two of the doors result in a net gain over trials and the other two doors result in a net loss over trials. Results were consistent with results from the original version indicating that poor performance on the task was not a result of reward sensitivity. Results remained significant when the authors repeated the study and controlled for working memory, leading the authors to conclude that children fail to anticipate future consequences in much the same way as individuals with ventromedial prefrontal damage.

Another recent study examined developmental aspects of the Gambling Task along with working memory and behavioral inhibition (Hooper, Luciana, Conklin & Yarger, 2004). This study included 145 participants between the ages of 9 and 17 who completed the original version of the Gambling Task, measures of verbal and nonverbal intellectual abilities (Vocabulary and Block Design subtests from the Wechsler scales), a measure of working memory (Digit Span subtest from the WISC-III), and a computerized go/no-go task. Participants were allowed to keep net earnings if they were ahead at the end of the Gambling Task. Reward amounts were altered so that disadvantageous decks had a reward of $0.25 and advantageous decks a reward of $0.10 or $0.15. Participants were grouped according to age (9-10; 11-13; and 14-17) and results revealed that the 14 to 17-year-olds made significantly more advantageous choices than the 9 to 10-year-olds.
The 11 to 13-year-olds did not differ significantly from the other age groups. When the Gambling Task was broken down into five trial blocks with 20 trials per block, it was found that 14 to 17-year-olds chose more advantageously in block four (trials 61-80) compared to the other two groups. In block five (trials 81 to 100) 14 to 17-year-olds chose more advantageously than the 9 to 10-year-olds only. On the go/no-go task and Digit Span, each age group scored significantly better than the age group below them. There was also a trend for girls to be better than boys, regardless of age, in responding to the go trials of the go/no-go task. Hierarchical regression analysis indicated that age accounted for a significant proportion of the variance in Gambling Task performance (as measured by net advantageous choices; $R^2 = .051$) and the addition of other variables (gender, full-scale IQ, go/no-go variable, and Digit Span) did not significantly increase the predictive power of the model.

These studies provide more evidence for the continued development of the prefrontal cortex throughout adolescence by demonstrating better Gambling Task performance in older adolescents. Unfortunately, no physiological measures were used in these studies. As a result, little is known about developmental aspects of somatic markers and whether they play a role in the improved performance.

*Individual Differences in Somatic Markers and Gambling Task Performance*

Bechara and colleagues’ research using the Gambling Task has consistently found that patients with prefrontal damage perform disadvantageously as a result of a decision-making deficit. However, they have noted that not all of their normal controls perform advantageously (Bechara, Damasio & Damasio, 2000). Approximately 20% of normal subjects who describe themselves as high risk-takers in real life perform
disadvantageously on the Gambling Task (Bechara et al., 1999). In some studies as many as 34% of normal controls performed below a cutoff score used to determine impaired performance (Bechara & Damasio, 2002). Furthermore, this cutoff score was developed based on the impaired performance of individuals with lesions to the ventromedial prefrontal cortex. This finding suggests that a percentage of normal controls show performance on the Gambling Task similar to that of the ventromedial lesion group.

Analysis of the SCR data reveals that normal controls often have anticipatory SCRs to the bad decks that are slightly lower than those to the good decks (Bechara et al., 1999). Normal individuals who choose advantageously exhibit higher anticipatory SCRs to bad decks higher than to good decks. According to the research by Bechara and colleagues, unlike prefrontal damaged patients, normal controls that perform disadvantageously on the Gambling Task do generate anticipatory SCRs whereas patients with lesions do not. Also, although patients with prefrontal lesions perform normally on other tasks of executive function, their performance is impaired on the Gambling Task. In a normal population, Gambling Task performance may be related to measures of intelligence and executive functioning (concept formation, perseveration, and ability to maintain set; Tsanadis & Suhr, 2002). This begs the question as to whether risk-taking is related to a more general decision-making deficit.

Bechara and colleagues argue that since these high risk-taking normal controls exhibit somatic states that signal possible negative consequences of a choice, risk-taking is not the same as impaired decision-making. One study has shown that prefrontal lesion patients risked less of their accumulated reward than controls, suggesting a pattern of conservative behavior (Rogers, Everitt, Baldacchino, Blackshaw, Swainson, Wynne,
Baker, Hunter, Carthy, Booker, London, Deakin, Sahakian, & Robbins, 1999). Despite this conservative pattern, their choices were still suboptimal. However, this conclusion may be premature. The risk-taking pattern exhibited by normal controls may be the result of prefrontal dysfunction although the dysfunction may not be as extreme as that seen in prefrontal lesions patients. It is also possible that an interaction between impaired decision-making and reward sensitivity may explain risk-taking behavior in a manner more consistent with Bechara’s view.

The conclusion drawn by Bechara and colleagues, that poor performance by risk-takers from the general population is not the result of a decision-making deficit, seems to ignore the possibility that decision-making occurs across a continuum, with somatic states being an important part of determining where someone falls on the continuum. For example, the stronger the somatic marker related to a potential disadvantageous choice, the less often the individual makes that choice, or the sooner they stop making it. Also, the prefrontal lobes may be conceptualized as the point where affective information enters the executive-cognitive system and influences decision-making. Bechara and colleagues’ acknowledge that cognitive elements are used in the decision-making process (Bechara et al., 2000); and, in their view, somatic states signaling possible negative outcomes are enacted, but higher cognitive processes can override these signals. These signals can be thought of as affective biases and in patients with prefrontal lesions, these biases never enter the decision making process. However, a complete breakdown in a system as a result of damage does not preclude the possibility of normal variation in intact individuals. Also, it would seem that the idea of higher cognitive processes that override affective biases is suggestive of a decision-making system that would be
relevant to risk taking behavior. Furthermore, the strength of the affective biases should
determine how likely they are to be overridden by higher cognitive processes. On the
other hand, one can argue that cognitive processes are greatly influenced by the affective
biases. In either case, it appears that the possibility of the relationship between risk-taking
behavior and prefrontal lobe function is the result of affective information and cognition
influencing each other in an integrated decision-making system. This system would likely
be sensitive to dispositional factors, which would, in turn, influence the decision-making
process in risk-taking situations. This brings up the question of what individual difference
factors can explain the variation in Gambling Task performance.

Some research has shown that personality characteristics are related to
performance on the Gambling Task and other risk-taking tasks. Addison and Schmidt
compared low and high shy females on a gambling game (1999). In this study, 177
undergraduate females were recruited and screened using the Cheek Shyness Scale. From
the larger sample, 17 were selected for high shyness (upper 25%), and 17 for low shyness
(bottom 25%). Participants completed the gambling game by first choosing a monetary
prize and cutoff point, and then picking a chip from a container that contained 100 chips
labeled 1-100. The instructions indicated that whatever cutoff point was chosen, in order
to win, the chip chosen had to be equal to or higher than the cutoff. The lower the cutoff
number, the higher the probability of winning. The prize for winning increased as the
probability of winning decreased. In addition, heart rate measures were taken for two
minutes prior to the game (baseline) and continuously recorded for three minutes during
the game. Separate ANOVA were performed comparing shy (high, low) for the gambling
pick and heart rate change. A main effect was found for both the gambling pick and heart
rate change. High shy females were significantly more likely to select smaller bets that were associated with greater chance of winning. In addition, they displayed a significantly greater increase in autonomic activity during the task compared to low shy females.

A study by van Honk (2002) utilized the Gambling Task in a sample of college students. A screening pool of undergraduates (n=525) completed the BIS/BAS scale. The median was calculated for the BIS and BIS and participants scoring within a three point range of the medians were discarded. Next, differences scores were calculated for BAS minus BIS and BIS minus BAS and the most extreme scores of the two groups were selected for participation. The final sample included 16 participants scoring low on BIS/high on BAS, and 16 subjects scoring low on BAS/ high on BIS (8 males and 8 females for both groups). The authors considered the extreme BAS scores as psychopathic and the extreme BIS scores as “non-Psychopathic.” Gambling Task performance was broken into 5 blocks of 20 trials. An ANOVA was conducted using over these five periods with group (low vs. high psychopath) and gender as between subject factors. There were no significant effects or interactions for gender. A significant interaction for group was found ($p = .012$). The low psychopathic group performed normally on the Gambling Task, but the high psychopathic group performed similar to prefrontal lesion patients in that they continued to make disadvantageous selections throughout the task. A significant effect was found between groups on the fifth block ($p = .003$), with high psychopathic individuals continuing to make disadvantageous selections and low psychopathic individuals making more selections from advantageous decks. It is important to note that these groups represented subclinical populations and thus the
findings reflect an individual difference paradigm more than a comparison of normal individuals to a clinical population (van Honk, 2002). In addition, Bechara and colleagues` work with substance dependent individuals suggests that while one group is similar to prefrontal patients in their psychophysiological responses to prefrontal patients, the other group appears hypersensitive to reward and insensitive to punishment (Bechara et al., 2002). It can be concluded that this hypersensitivity leads to a decision-making deficit that leads to risk-taking behavior. Again this finding is consistent with Gray`s behavioral activation system (BAS) and behavioral inhibition system (BIS; 1979), as well as other theories that account for individual differences in risk-taking behavior based on a trait or dispositional perspective (Cloninger, 1987; Zuckerman, 1991).

In recent years, variability in Gambling Task performance and psychophysiological responses in the general population has become an active area of research. A 2004 study by Carter and Pasqualini reported findings consistent with the somatic marker hypothesis in a normal population. This study involved 30 women with no reported history of neurological or psychiatric problems. This study used the Gambling Task and participants were randomly assigned to one of two groups. One group were administered the Gambling Task in the standard form while the other group were administered the Gambling Task with real money and individuals in the latter group could keep any money they won above the initial stake they were provided by the examiners. Skin conductance level was measured for each individual during the Gambling Task for both anticipatory and reactive responses. Anticipatory responses were defined as the amplitude of the first SCR peak from nine seconds after the signal to choose a card was given until two seconds after the next signal to choose a card. This
varies slightly from the method of Bechara and colleagues, who define anticipatory responses as occurring five seconds after the selection of a card and up until the selection of the next card (Bechara et al., 1999). This study also explored personality variables using the Eysenck Personality Questionnaire (EPQ-R).

Results of this study found no differences between the fake money standard Gambling Task protocol and the real money protocol. A significant positive correlation was found between mean beneficial SCR and amount of money won on the Gambling Task. This suggests that a stronger autonomic response is associated with better Gambling Task performance and this relationship may occur on a continuum.

Neuroticism as measured by the EPQ-R was found to be positively and significantly correlated with amount of money won. A marginally significant relationship was found between Neuroticism and mean beneficial anticipatory response. When the relationship between Neuroticism and amount of money won was examined with mean beneficial anticipatory response partialled out, the correlation was no longer significant, suggesting the relationship between Neuroticism and amount of money won may be mediated by mean anticipatory SCR.

There is some question about the methodology of this study. For example, in the majority of Gambling Task research, including that by Bechara, the Gambling Task variable used is the selection of disadvantageous and advantageous decks and not the amount of money won or lost as used by Carter and Pasqualini. Also, Carter and Pasqualini used a manual version of the Gambling Task because an initial pilot study found that individuals taking the computer version stopped responding autonomically after a few trials.
A study by Crone, Somsen, Van Beek and Van der Molen (2004) examined both SCR and heart rate during Gambling Task performance. The authors tested 96 participants with a variation of the Gambling Task the authors developed for use with children that retains the win and loss schedule of the original Gambling Task (Crone & van der Molen, 2004). The authors calculated an anticipatory SCR value by measuring skin conductance level (area under the curve) 5,000 ms before a response. For each response, the mean skin conductance level was compared to the lowest microsiemens values for each individual. Thus, a difference score between the lowest (baseline) values and a given trial represented an anticipatory response. For heart rate, inter-beat interval (IBI) responses were computed by calculating the difference between the IBI concurrent to the response and the IBI preceding the response. Participants were divided in three groups based on their performance on the Gambling Task: bad, moderate, and good. The good and moderate performers showed statistically significant differential skin conductance activity preceding advantageous and disadvantageous choices (larger responses prior to disadvantageous selections). For heart rate, the good performers had a significant slowing of heart rate prior to selections with a high frequency of punishment. No significant results were found for poor and moderate performers on the heart rate measure.

Suzuki, Hirota, Takasawa and Shigemasu (2004) also explored the somatic marker hypothesis, as measured with the Gambling Task, in a normal population. Their study involved 40 undergraduate students at the University of Tokyo (27 men and 13 women). The participants completed a modified version of the Gambling Task that used 80 instead of 100 trials and a ten second time lapse between trials. Skin conductance was
measured for both anticipatory and outcome appraisal responses. They defined anticipatory responses as the largest SCR (area under the curve) occurring during the ten-second time period prior to a selection. After the completion of the Gambling Task, participants rated the risk of each deck on a scale ranging from 1 (very dangerous) to 7 (very safe). A significant negative relationship was found between amplitude of appraisal SCRs in the early trials and poor performance on the Gambling Task. However, the authors of this study were unable to replicate the anticipatory SCR finding of Bechara and colleagues.

At this point in time, there is some inconsistency in the findings of studies examining the autonomic responses that are the hallmark of the somatic marker hypothesis. As discussed above, Carter and Pasqualini (2004) had findings consistent with the somatic marker hypothesis, but there are some questions about their methodology and their first attempt was unsuccessful. Crone et al. (2004) obtained results consistent with the somatic marker hypothesis but used a variation of the Gambling Task and a different procedure to compute anticipatory responses. Suzuki et al. (2004) were unable to replicate the general autonomic response findings. The inconsistent results of these studies may stem from the differing definition of anticipatory responses. Each study has used a slightly different method and this could account for the inconsistent findings. An additional problem is that some of the methods can cause confusion between the physiological reaction to consequences of a prior selection and the anticipatory response to the subsequent selection. The current study improved upon prior methodologies by using the 10-second between trial period and defining the anticipatory response as the highest skin conductance level in the five second period prior to a selection. It was hoped
that such changes to the paradigm would reduce the likelihood of measuring an appraisal skin conductance level from the previous trial. In addition, a new method was used that forces participants to choose from good and bad decks while measuring skin conductance level, with the goal being to assess skin conductance level data with less interference from previous trials and have a better comparison between anticipatory responses to advantageous and disadvantageous selections.

The somatic marker hypothesis has also come under fire in a 2004 study by Heims, Critchley, Dolan, Mathias and Cipolotti. They compared Gambling Task performance of healthy participants and individuals with pure autonomic failure (PAF; a condition that results in a lack of integrated central feedback of autonomic changes that would normally accompany behavior). The results indicated that the PAF participants performed better on the Gambling Task than the healthy participants. These findings taken as whole do not disprove the somatic marker hypothesis but they do raise questions regarding the comprehensiveness of the theory and its ability to account for different aspects of risk-taking and other disadvantageous behaviors. These studies may be an indication that the proper place for the somatic marker hypothesis is as a single piece of a multi-component theory of risk-taking and disadvantageous behavior instead of a stand alone theory meant to explain such behavior. The current study treats somatic markers as one variable among several that are involved in risk-taking behavior.
To better understand the processes involved in risk-taking behavior, it makes sense to integrate personality and decision-making variables, with the goal being to explain individual differences in participation in risk-taking behavior. The research presented above suggests that personality and affective decision-making theories have more in common than is apparent at first glance. The argument offered here is that dispositional theories of personality can be effectively explained by Gray’s BIS/BAS theory. Furthermore, Damasio’s somatic states can be explained in terms of a more sophisticated and updated version of Gray’s theory. At least one recent study has implicated a biologically based reward and punishment system in Gambling Task performance. Schutter and van Honk based their study on the findings of previous studies that suggest the ratios between slower and faster waves of the electroencephalogram (EEG) measure the motivation balance of this system (2005). The results of their study, which used 28 healthy participants, found that higher versus lower EEG ratios were associated with poorer Gambling Task performance. Although still speculative at this point, this study indicates the possibility of a brain-based motivational system, akin to Gray’s BIS/BAS, that is related to Gambling Task performance. As a result, it can be tentatively inferred that what is being measured by the Gambling Task is BIS/BAS sensitivities. The affective decision-making system can be considered a cognitive decision-making system that is influenced by an individual’s dispositional BIS/BAS sensitivities. It is argued that the location of this system is the ventromedial prefrontal cortex and this system is part of the broader system of executive functions. It
follows from this that an explanation of risk-taking behavior would need to account for 3 broad components (Figure 4). Affect is considered a confound at this time since research suggests that it plays a role in decision-making, but its relationship to Gambling Task performance is at this time unclear.

Figure 4. The Components of Risk-Taking Behavior

The present study was designed to examine the decision-making variables discussed here and explore their relationship to risk-taking behavior in an undergraduate population. This study examined specific aspects of executive functioning (decision-making, cognitive impulsivity, concept formation), disposition (based on Gray’s BIS/BAS model), affect, and autonomic response in order to see if these variables are related to self-reported expected participation in risk-taking activities.
The first goal of the study was to examine the relationship between measures of executive functioning and risk-taking behavior. Specifically, the first hypothesis was that poorer performance on measures of executive function would be related to higher levels of engagement in risk-taking behavior. In addition, since the Gambling Task is the measure that is associated with the neuroanatomy most linked to risk-taking behavior in brain injured individuals (ventromedial prefrontal cortex), performance on this task was predicted to account for the most variance in risk-taking behavior.

A second goal of the present study was to examine the relationship among the executive functioning measures. The second main hypothesis was that Gambling Task performance would not be significantly related to measures of reasoning but would be related to impulsivity.

A third goal of the study was to explore the relationship of BIS/BAS to Gambling Task performance. Consistent with Gray’s theory, the third main hypothesis was that individuals who are more BAS oriented would perform worse on the Gambling Task than individuals who are more BIS oriented.

A fourth goal of the present study was to explore the somatic marker hypothesis. The fourth main hypothesis of the present study was that individuals with better Gambling Task performance would have greater anticipatory SCR to disadvantageous selections compared to individuals with poorer Gambling Task performance. This is based on previous research by Bechara and colleagues, Carter and Pasqualini, and Crone et al., and the aim of the present study was to replicate their findings.

Finally, although the CARE was developed on a college population including both females and males (Fromm et al., 1997), there is not a lot of information regarding
gender differences on this scale. Research indicates that, in the general population, significant gender based differences exist in risk-taking behavior (Grant, 1997; Helzer, Canino, Yeh, Bland, Lee, Hwu & Newman, 1988). As a result, in the current study, gender differences on the CARE were examined and accounted for when exploring the above hypotheses.

Method

Participants

Participants were recruited from the undergraduate population at Ohio University. Participants received course credit (1 credit per hour of participation) for their participation in the study. Participants signed up for a designated time on an Internet-based sign-up system. Participants read a brief description of the study (Appendix A) and signed up by putting their name in one of the designated time slots. To predict the number of cases required for sufficient power, a general rule was used that takes effect size (R^2) into account. This rule states that N is equal to or greater than (8/f^2) + (m-1)

where f^2 = R^2/1 - R^2, and m=number of independent variables (Green, 1991). According to this rule, for a study with six independent variables that is intended to demonstrate an effect size of .10, a minimum of 78 participants are required. A total of 90 participants took part in the current study (44 Male and 46 female). The age range was 18 to 28, with a mean age of 20.01 years (S.D. = 1.91; Median= 20.00). Psychophysiological data for four participants was unusable due to equipment failure and an additional three
participants had unusable data for the second psychophysiological trial for the same reason.

**Cognitive Measures**

*Wisconsin Card Sorting Test-64 card version (WCST-64).* The WCST is intended to assess concept formation and reasoning. It consists of 64 cards with one to four symbols in one of four colors printed on them. No two cards are identical. The participant’s task is to place each card, one by one, under four stimulus cards, according to a principle that the participant must deduce from the examiner’s responses to the participant’s placement of the cards (Kongs et al., 2000). The variables from the WCST-64 that were used in the present study were categories completed, perseverative errors and loss of set. The standardized instructions were read to the participants as follows:

*This test is a little unusual because I am not allowed to tell you very much about how to do it. You will be asked to match each of the cards in these decks, to one of these four key cards (point to each stimulus card in succession). You must always take the top card from the deck and place it below the key card you think it matches. I cannot tell you how to match the cards, but I will tell you each time whether you are right or wrong. If you are wrong, simply leave the card where you have placed it and try to get the next card correct. There is no time limit on this test. Are you ready? Let’s begin.*

An examination of test-retest reliability for the WCST using a one month interval between administrations revealed coefficients ranging from .39 to .72, with a mean of .57 (Heaton et al., 1993). Recent studies have found significant practice effects for WCST variables in one year test-retest intervals (Basso, Bornstein, & Lang, 1999). When using a
test-retest interval of approximately 2.5 years, coefficients greater than .90 were found for all WCST variables (Ozonoff, 1995). The WCST-64 was examined using an average test-retest interval of 6.7 weeks. Coefficients for the WCST-64 were: total number of errors .85, perseverative responses .72, perseverative errors .76, nonperseverative errors .60, conceptual level responses .79 (Kongs et al., 2000).

Validity of the WCST has been empirically demonstrated in lesion studies. Damage to the some or the entire dorsolateral frontal region has been shown to negatively affect WCST performance (Milner, 1963). Heaton found that adults with lesions involving frontal areas performed significantly worse than adults with lesions in non-frontal areas (Heaton, 1981, 1993).

The Gambling Task. The computerized version of the Gambling Task was used. In this version the participant sees four decks of cards on a computer screen. The decks are labeled A’, B’, C’, and D’ at the top end of each deck. The participant clicks on one of the four decks with a mouse. When the participant clicks on a deck to pick a card, the computer generates a sound and the face of the card appears on top of the deck. A message is then displayed indicating how much money the participant has won and then indicating if they have lost money. A green bar on top of the computer screen indicates the amount of money won or lost after each selection. A gain in money is indicated by a proportional increase in length of the green bar and a loss by a proportional decrease in the green bar. After the money has been added or subtracted the face of the card disappears and the participant may select another card. Each of the four decks contains 60 cards with 30 being black face and 30 being red face. For the disadvantageous decks (A’ and B’), the frequency of delayed punishment is increased by 10% in every block of ten
cards and the magnitude remains the same, for deck A', and the magnitude of an 
individual delayed punishment is increased in every block of ten cards by an amount 
equal to the increase in deck A'. This leads to selections from these decks resulting in 
greater loss. Parallel increases in frequency and magnitude of delayed punishment occur 
in the advantageous decks (C' and D'), however they occur in the positive direction (i.e. 
towards larger gain; Bechara, Tranel & Damasio, H., 2000). The instructions were read to 
participants as follows:

*In front of you on the screen, there are four decks of cards: A’, B’, C’, and 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*
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. Also, each deck contains an equal number of cards of each color, so the color of the cards does not tell you which decks are better in this game. So you must not try to figure out what the computer is doing. All I can say is that some decks are worse than the others. You may find all of them bad, but some are worse than the 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 all decisions on what to do with it should be made as if you were using your own money.

The validity of the Gambling Task has been demonstrated in patients with damage to the ventromedial prefrontal cortex. Despite displaying intact cognitive profiles, patients with ventromedial prefrontal cortex lesions perform poorly on the Gambling Task compared to controls (Bechara et al., 1994). Using the computer version of the Gambling Task, with progressive increase in delayed punishment, normal controls shift their preference towards the good decks (C’, and D’) over time, whereas ventromedial lesion patients failed to demonstrate this shift (Bechara, Tranel & Damasio, H., 2000). For the present study, the participant’s selections from the disadvantageous decks (A’ and B’) were added together and that total was subtracted from the sum of
advantageous deck selection (C’ and D’). Scores range from −100 to +100, with a
negative score indicating a preference for bad decks and a positive score indicating a
preference for good decks.

Go/no go. This task requires the individual to make a response to a go signal and
inhibit the response to the no go signal. The task is made more difficult by reversing the
meaning of the signals. For this study, individuals were instructed to follow the directions
of the examiner. The participants were instructed to knock either once or twice
depending on what is heard for that trial. Next the individual was instructed to knock the
reverse of what they are told. So if the instructions were “knock twice,” the individual
had to knock once for a correct response. The third series of trials required the participant
to knock when told to go and to not knock when told to stop. The final trial required the
participant to knock when told to stop and not knock when told to go. The variable used
in this study was total number of errors made across all trials.

A recent study by Horn, Dolan, Elliott, Deakin and Woodruff (2003) explored
performance on a computerized go/no go task, self-report measures of impulsivity
(Eysenck’s Impulsivity Scale, Barratt’s Impulsivity Scale) and utilized functional
resonance imaging of the brain. Nineteen healthy, right-handed males were recruited for
the study. Their ages ranged from 18 to 50. The Structured Clinical Interview was
administered to rule out psychiatric disorders. The results indicated that the most
significant neural responses during the go/no go task were found in the right anterior
lateral anterior orbitofrontal cortex. Medial prefrontal cortical region were also activated.
In addition, impulsivity as measured by Eysenck’s Impulsivity Scale was positively
associated with activation in the right posterior orbitofrontal cortex. The final conclusion
of the authors was that during response inhibition there are activations in the anterior lateral orbitofrontal cortex and paralimbic areas (Horn et al., 2003).

Further evidence for the validity of the go/no go task as a measure of prefrontal cortex functioning comes from Gondo, Shimonaka, Senda, Mishina, & Toyama (2000). This study used positron emission tomography (a measure of regional cerebral blood flow) on 11 participants while they completed a computer version of the go/no go task. The right prefrontal cortex was found to be significantly activated during the go/no go task when compared to a control task.

**Risk-Taking Measure**

The CARE (Cognitive Appraisals of Risky Events Scale) is a 30-item self-report measure that consists of six factor-analytically derived scales that represent six categories of risk-taking behavior (Fromme, Katz, & Rivet, 1997; Appendix B). The scales are as follows: 1) Illicit Drug Use, 2) Aggressive/Illegal Behaviors, 3) Risky Sexual Activities, 4) Heavy Drinking, 5) High Risk Sports, 6) Academic/Work Behaviors. The CARE uses a seven point Likert response scale (1=not at all likely; 7=extremely likely) to rate three types of outcome expectancies: 1) Expected Risk (ER), 2) Expected Benefit (EB), and 3) Expected Involvement (EI). The CARE has also been used to assess participation in prior risk-taking behavior (Katz et al., 2000). Furthermore, the CARE was developed for use with a college population and was empirically developed with a college population (Fromme et al., 1997).

A reliability study revealed that the ER had a test retest (of ten days) $r = .51$ to $.65$, and EB from $r = .58$ to $.79$ for the subscales (Fromme et al., 1997). No test-retest data was reported for the full scale. Construct validity of the CARE was assessed using
the Social Conformity Questionnaire (SCQ; Newcomb & Bentler, 1989) and the Impulsive Unsocialized Sensation Seeking Scale (IMPUSS). The IMPUSS scale is part of the Kuckerman-Kuhlman Personality Questionnaire-III (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). The four traditional risk behaviors (drug and alcohol use, unsafe sex, and aggression), EB, EI, and frequency of involvement ratings were significantly positively correlated with IMPUSS scores and significantly negatively correlated with SCQ scores (Fromme et al., 1997). The strongest pattern of association was between trait measures and EB (correlations ranging from .23 to .41 for the four traditional areas of risk behaviors) and EI (correlations ranging from .17 to .51 for traditional areas of risk behaviors (Fromme et al., 1997). Criterion validity was assessed by having participants return ten days after the initial assessment and complete a frequency of involvement in risk-taking behaviors scale for the previous ten days. The results indicate that past behavior was significantly associated with current behavior except for Risky Sexual Activities (Fromme et al., 1997). Outcome expectancies accounted for significant incremental variance in current risk taking behavior, beyond that predicted by past behavior. EB contributed the greatest amount of variance in drug use, heavy drinking, and aggression. EI contributed the most variance in academic/work behaviors. The combined expectancies were significantly associated with reported frequency of current risky sexual behavior, although the independent contributions of ER, EB, and EI were not supported (Fromme et al., 1997).

Generalizability and external validity were assessed by administering the CARE to a clinical sample and a group of high-risk sports enthusiasts (Fromme et al., 1997). The clinical sample consisted of 38 individuals that reported long-term problems with alcohol
and illicit drugs. They were in treatment for an average of 3.9 months with an average of 2.9 previous treatment efforts. The sports enthusiast sample consisted of 58 individuals who reported an average of four years involvement in high-risk sports such as rock climbing, caving, and scuba diving. Participants were administered the ER, EB, and frequency of involvement measures of the CARE. Simultaneous regression analysis revealed that outcome expectancies were significantly associated with involvement for all six risky activities in both samples (Fromme et al., 1997). For the clinical sample, R² ranged from .13 to .44 (High Risk Sports and Aggressive/Illegal Behavior respectively) and for sports enthusiasts .08 to .58 (Academic/Work Behaviors and Aggressive/Illegal Behavior respectively; Fromme et al., 1997). For the current study, the total Expected Involvement scale score of the CARE was used as the measure of risk taking behavior.

**Personality Measure**

The Behavioral Inhibition/Behavioral Activation Scale (BIS/BAS scale; Carver & White, 1994; Appendix C) is a 20-item self-report questionnaire designed to measure Gray’s personality model of behavioral inhibition and activation. The psychometrics of the scale have been tested in several studies by independent research groups (Carver & White, 1994; Jorm, Chistensen, Henderson, Jacomb, Korten & Rodgers, 1999; Heubeck, Wilkinson & Cologon, 1998). The BIS scale yields one measure of behavioral inhibition and the BAS scale yields three subscales: reward responsiveness, drive, and fun seeking (Carver & White, 1994; Jorm et al., 1999). For the purpose of this study, only the BIS and an overall BAS score were used. In addition, the scores of the BIS/BAS scale were combined to establish a single score representing whether the person is more BIS or BAS oriented. This will be achieved by taking the BIS score and subtracting it from the overall
BAS score. A positive score will indicate a higher BAS orientation and a negative score will indicate a higher BIS orientation.

Studies indicate that the BIS/BAS scale has good reliability. Cronbach’s alpha for BIS was 0.76 and for BAS was 0.83 (Jorm et al., 1999). Reliability for the BAS subscales is somewhat lower, although still acceptable (Cronbach’s alpha, 0.65 for reward responsiveness, 0.80 for drive and 0.70 for fun seeking; Jorma et al., 1999). Test-retest reliability was assessed using a sample of 113 subjects who were retested eight weeks after an initial testing. Test-retest correlations were .66 for BIS, .66 for drive, .59 for reward responsiveness, and .69 for fun seeking. A study conducted at the same university as the present study found test-retest reliabilities of .73 for BIS and .74 for BAS for the 34 participants who were selected for the study. For 57 individuals who were excluded, test-retest reliabilities were .61 for BIS and .51 for BAS.

Measure of Affect

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988; Appendix D) is a 20-item scale that consists of two factor-analytically derived scales representing positive and negative affect. Participants rate themselves on each item using a 5-point scale (1 = very slightly, 5 = extremely) with instructions asking them to base their answers on how they feel in the moment. Internal consistency reliabilities are .89 for the positive affect scale, and .85 for the negative affect scale, and eight week test-retest reliabilities are .54 for the Positive Affect scale and .45 for the Negative Affect scale with (Watson et al., 1988). Evidence for the validity of the PANAS comes from correlations with the Hopkins Symptom Checklist and the Beck Depression Inventory with the Negative Affect scale (positive correlations) and Positive Affect scale (negative
correlations; Watson et al., 1988). The score for the Negative Affect scale was subtracted from the score on the Positive Affect scale and this value was used in the statistical analysis.

Psychophysiological Measure

Skin conductance level (SCL) in microsiemens was recorded using the BIOPAC Systems MP-100 and analyzed using AcqKnowledge software. Electrodes were attached to the palmer side of the medial phalanx on the second and third fingers of the left hand. The wells of the electrodes were leveled with electrode gel prior to placement. After placement of the electrodes, participants sat in a quiet room for five minutes to allow participants to acclimate to the environment. Previous research by Bechara has found that punishment/reward SCRs occur in the five seconds following a deck selection (Bechara & Damasio, 2002). In order to better differentiate punishment/reward from anticipatory SCL, the time interval between Gambling Task trials was extended to 10 seconds. For this study, the SCL (area under the curve) obtained in a five second time period prior to card selection on the Gambling Task was used. An SCL for each selection was obtained in this way. The SCLs for each disadvantageous and advantageous selection were averaged separately. This resulted in a mean disadvantageous selection and advantageous selection anticipatory SCL score for each participant. The mean of the advantageous SCLs were subtracted from the mean disadvantageous SCLs from each participant. This will allow for one mean SCL difference score for each participant with a higher number reflecting a greater anticipatory response to disadvantageous selections.

An additional ten trials of the Gambling Task were administered where the participant was instructed to choose between two options (A or B; C or D) as determined
by the experimenter. Anticipatory SCL was measured for each selection using the five second period prior to a deck selection. The SCLs for disadvantageous selections were averaged, as were SCLs for advantageous selections. The advantageous selections were subtracted from the disadvantageous selections resulting in a mean SCL difference score for each participant.

**Experimental Procedure (Table 1)**

Participants were tested in the Clinical Neuropsychology Research Lab in Porter Hall at Ohio University. Participants were led to a private room and, after providing informed consent (Appendix E) and completing a demographic questionnaire (Appendix F), they were instructed to complete the CARE questionnaire, BIS/BAS scale, and the PANAS. Next, participants were administered the WCST and the Go/No Go test. Electrodes were then attached and participants sat in a quiet room to establish a baseline for SCL recording. Participants were then presented with the computerized version of the Gambling Task. After completing the Gambling Task, participants were informed that they would have ten additional card selections on the Gambling Task. They were told that the examiner would give them the choice between two decks. The selections were determined ahead of time and consisted of five choices between advantageous decks (C’ or D’) and five choices between disadvantageous decks (A’ or B’). EDA was monitored and marked at the point of each selection.
Table 1

*Procedure for Experimental Session*

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Review informed consent</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Demographic Data</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Questionnaires</td>
<td>CARE, PANAS, BIS/BAS</td>
</tr>
<tr>
<td>20</td>
<td>Cognitive Tasks</td>
<td>WCST, Go/No Go</td>
</tr>
<tr>
<td>5</td>
<td>Electrode Placement</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Baseline</td>
<td>EDA</td>
</tr>
<tr>
<td>15</td>
<td>Cognitive Task</td>
<td>Standard Gambling Task</td>
</tr>
<tr>
<td>5</td>
<td>Cognitive Task</td>
<td>Ten additional deck selection on the Gambling Task.</td>
</tr>
<tr>
<td>5</td>
<td>Debriefing</td>
<td></td>
</tr>
</tbody>
</table>

Results

*Descriptive Statistics*

Means, standard deviations, and ranges for each variable are presented in Table 2 (full sample), Table 3 (females), and Table 4 (males). Distribution of the variables was
explored using SPSS Explore. Several of the variables were found to deviate significantly from normality. Go/No Go Test-Errors and Perseverative Errors were positively skewed. Also, Go/No Go errors demonstrated limited variability, with 65.6% of participants not committing an error and an additional 25.6% committing only one error. The range for the Go/No Go test was six and the interquartile range was one. Categories Completed also demonstrated limited variability with a range of five and interquartile range of two. The two physiological variables, mean SCL difference score for the standard Gambling Task and the 10 forced trials, were positively skewed. Due to skewness, a logarithmic transformation was used on Go/No Go and Perseverative Errors. Skewness was adequately reduced for Perseverative Errors; however, Go/No Go remained problematic and was thus removed from all subsequent analyses. The two physiological variables were transformed using a logarithmic transformation to reduce skewness.

Gender Differences on the CARE, Gambling Task, and BIS/BAS Scale

To explore gender differences, independent samples $t$-tests were performed. Males had significantly higher CARE-EI scores than females, $t (88) = -3.38, p = .001$. No significant difference was found between mean Gambling Task scores of males and females, $t (88) = 1.1, p = .27$. Males had a significantly higher BAS to BIS ratio, $t (88) = -2.32, p = .02$. Given these results, gender was entered as a covariate on all subsequent analyses using CARE-EI and BIS/BAS scores to control for sex differences.

Hypothesis 1: Relation of Cognitive Variables to CARE Scores

A hierarchical linear regression was conducted to determine if cognitive variables could account for variance in expected participation in risk-taking activities as measured by the CARE-EI. Evaluation for multicollinearity indicated a problem, and further investigation
suggested it was the result of a significant association between Categories Completed and Perseverative Errors. Due to problems with multicollinearity and the limited variance, Categories Completed was dropped from the analysis. Using a $p < .001$ criterion for Mahalanobis distance, no multivariate outliers were identified in the final model, and the assumptions of normality, linearity and homoscedasticity of residuals were satisfied.

Table 5 displays a summary of the hierarchical regression analysis. Gender and PANAS score were entered as covariates in Step one and two, respectively; and Gambling Task performance and (log of) Perseverative Errors were entered in Steps three and four respectively. The covariate Gender accounted for the most variance, $R^2 = .12$, $p < .01$. None of the hypothesized predictors accounted for a significant amount of the variance in CARE-EI scores. Gambling Task performance ($\Delta R^2 = .03$, $p = .11$) was the closest to achieving significance.

**Hypothesis 2: Relationships Among Cognitive Variables**

Initially, a regression analysis was planned using three of the cognitive variables to determine which could account for the most variance in Gambling Task Performance. However, as stated above, Go/No Go and Categories Completed had such limited variance that they were deemed unsuitable for use in this analysis. No relationship was found between log of Perseverative Errors and Gambling Task performance, $r = -.09$, $p = .41$.

Due to the significant relationship between gender and CARE-EI scores, two additional hierarchical regression analyses were performed, for males and females separately. PANAS score was entered as a covariate in Step one, with Gambling Task performance and number of Perseverative Errors as predictors in Steps two and three.
respectively. Table 6 and Table 7 display the summary of the hierarchical regression analyses for females and males respectively. For females, none of the variables accounted for a significant amount of the variance in CARE-EI scores, and PANAS score accounted for the most variance ($R^2 = .04, p = .22$). For males, Step two was significant, with Gambling Task Performance accounting for 11% of the variance in CARE-EI scores ($\Delta R^2 = .11, p = .03$). Log of Perseverative Errors approached significance on Step three ($\Delta R^2 = .07, p = .07$).

**Hypothesis 3: Dispositional Behavioral Activation/Behavioral Inhibition Balance and Performance on the Gambling Task**

Scores on the BAS/BIS scale were divided into top third, middle third and bottom third, representing a higher BAS to BIS ratio, a relative balance between BAS and BIS, and a higher BIS to BAS ratio, respectively. Mean Gambling Task scores for each group are presented in Table 8. A one-way analysis of covariance of the three BAS/BIS ratio groups on Gambling Task performance was conducted, controlling for gender and PANAS score. As predicted, there were significant group differences in Gambling Task performance, $F (2, 86) = 11.92, p < .001$. The covariate PANAS score was also found to be significantly related to Gambling Task score ($p < .001$) with individuals higher in positive affect performing better than those with more negative affect. A significant relationship was not found for the covariate Gender ($p = .62$). Post hoc analysis, using the Bonferroni multiple comparison procedure, found significant differences between the top third and middle third ($p < .001$), and the top third and bottom third ($p < .01$). As expected, individuals who had a relative balance between the BAS and BIS, and
individuals with higher BIS to BAS ratio performed better on the Gambling Task than
individuals with a higher BAS to BIS ratio.

Table 2

Descriptive Statistics for All Variables (Full Sample, N = 90)

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARE-EI</td>
<td>84.00</td>
<td>28.47</td>
<td>140</td>
</tr>
<tr>
<td>PANAS</td>
<td>14.14</td>
<td>7.82</td>
<td>41</td>
</tr>
<tr>
<td>Gambling Task</td>
<td>15.09</td>
<td>31.79</td>
<td>134</td>
</tr>
<tr>
<td>Go/No Go</td>
<td>.51</td>
<td>.95</td>
<td>6</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>10.32</td>
<td>6.93</td>
<td>32</td>
</tr>
<tr>
<td>Categories Completed</td>
<td>3.08</td>
<td>1.56</td>
<td>5</td>
</tr>
<tr>
<td>BIS/BAS</td>
<td>19.72</td>
<td>5.42</td>
<td>25</td>
</tr>
<tr>
<td>SCL (microsiemens)</td>
<td>.035</td>
<td>.13</td>
<td>1.01</td>
</tr>
<tr>
<td>SCL-10 Selections</td>
<td>.058</td>
<td>.19</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Note. CARE= Cognitive Appraisal of Risky Events Questionnaire-Expected Involvement; PANAS= Positive Affect Negative Affect Schedule; BAS= Behavioral Activation System; BIS= Behavioral Inhibition System; SCL= Skin Conductance Level.

Hypothesis 4: Anticipatory Psychophysiological Responsiveness and Gambling Task Performance

A paired samples t-test was performed to compare mean anticipatory SCLs of advantageous and disadvantageous selections. A significant difference was found for both the standard administration, $t(85) = -2.43, p = .02$, and for the ten forced choice trials, $t(82) = -2.81, p = .006$. Participants in the present study had significantly higher
anticipatory SCLs to disadvantageous selections, consistent with the somatic marker hypothesis. The remaining analyses were conducted using the log transformed mean disadvantageous and advantageous SCL difference scores (from this point referred to as mean SCL difference scores) for the standard Gambling Task administration and the 10 forced trials.

Gender differences were explored using independent samples $t$-tests. There was no difference in (log of) mean SCL difference scores between females and males for either the standard administration, $t(84) = -.001, p = .99$, or for the ten forced trials, $t(81) = -.74, p = .46$. Therefore, gender was not used as a covariate in subsequent analyses.

To examine the relationship between anticipatory physiological responses and Gambling Task performance, scores on the Gambling Task were divided into top third, middle third and bottom third based on performance. Log of mean SCL difference scores for each group are presented in Table 9. A one-way analysis of covariance of Gambling Task performance on (log of) mean SCL difference score was conducted, controlling for PANAS score. There was no difference in (log of) mean SCL difference score among the three groups, $F(2, 82) = .96, p = .39$. In addition, the covariate PANAS was not significantly related to mean SCL difference score ($p = .82$).

A comparison was also made for the 10 forced Gambling Task trials. Log of mean disadvantageous and advantageous SCL difference scores for each group are presented in Table 10. A one-way analysis of covariance of Gambling Task performance on (log of) mean SCL difference score on the ten forced trials was conducted controlling for PANAS score. There were no group differences on (log of) mean SCL difference score, $F(2, 79) = .98, p = .38$. The planned comparison between the top third and bottom third of
Gambling Task performance did show a trend for individuals in the top third of Gambling Task Performance to have a greater (log of) mean SCL difference score than individuals in the bottom third of performance ($p = .09$). The covariate PANAS score was found to have a significant relationship with (log of) mean SCL difference score ($p = .006$). A significant positive correlation was found, indicating increased positive affect was associated with greater difference between anticipatory SCL to disadvantageous and advantageous selections, $r = .32$, $p < .01$.

Table 3

*Descriptive Statistics for All Variables (Females, $N = 46$)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARE-EI</td>
<td>74.61</td>
<td>21.80</td>
<td>102</td>
</tr>
<tr>
<td>PANAS</td>
<td>13.59</td>
<td>7.57</td>
<td>32</td>
</tr>
<tr>
<td>Gambling Task</td>
<td>18.69</td>
<td>29.39</td>
<td>126</td>
</tr>
<tr>
<td>Go/No Go</td>
<td>.41</td>
<td>.58</td>
<td>2</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>11.04</td>
<td>7.53</td>
<td>32</td>
</tr>
<tr>
<td>Categories Completed</td>
<td>3.00</td>
<td>1.60</td>
<td>5</td>
</tr>
<tr>
<td>BIS/BAS</td>
<td>18.46</td>
<td>5.56</td>
<td>25</td>
</tr>
<tr>
<td>SCL (microsiemens)</td>
<td>.034</td>
<td>.14</td>
<td>.81</td>
</tr>
<tr>
<td>SCL-10 Selections</td>
<td>.046</td>
<td>.20</td>
<td>1.21</td>
</tr>
</tbody>
</table>

*Note.* CARE= Cognitive Appraisal of Risky Events Questionnaire-Expected Involvement; PANAS=Positive Affect Negative Affect Schedule; BAS=Behavioral Activation System; BIS=Behavioral Inhibition System; SCL= Skin Conductance Level.
### Table 4

**Descriptive Statistics for All Variables (Males, N = 44)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARE-EI</td>
<td>93.82</td>
<td>31.43</td>
<td>138</td>
</tr>
<tr>
<td>PANAS</td>
<td>14.70</td>
<td>8.12</td>
<td>39</td>
</tr>
<tr>
<td>Gambling Task</td>
<td>11.33</td>
<td>34.06</td>
<td>134</td>
</tr>
<tr>
<td>Go/No Go</td>
<td>.61</td>
<td>1.22</td>
<td>6</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>9.57</td>
<td>6.23</td>
<td>31</td>
</tr>
<tr>
<td>Categories Completed</td>
<td>3.16</td>
<td>1.52</td>
<td>5</td>
</tr>
<tr>
<td>BIS/BAS</td>
<td>21.04</td>
<td>4.99</td>
<td>20</td>
</tr>
<tr>
<td>SCL (microsiemens)</td>
<td>.035</td>
<td>.13</td>
<td>.920</td>
</tr>
<tr>
<td>SCL-10 Selections</td>
<td>.071</td>
<td>.17</td>
<td>.99</td>
</tr>
</tbody>
</table>

*Note. CARE-EI= Cognitive Appraisal of Risky Events Questionnaire-Expected Involvement; PANAS=Positive Affect Negative Affect Schedule; BAS=Behavioral Activation System; BIS=Behavioral Inhibition System; SCL= Skin Conductance Level.*

### Table 5

**Summary of Hierarchical Regression Analysis of Cognitive Variables and CARE-EI Scores (N = 90)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>18.40</td>
<td>5.75</td>
<td>.32**</td>
</tr>
<tr>
<td>PANAS</td>
<td>.35</td>
<td>.38</td>
<td>.10</td>
</tr>
<tr>
<td>Gambling Task</td>
<td>-.14</td>
<td>.09</td>
<td>-.16</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>12.04</td>
<td>11.11</td>
<td>.11</td>
</tr>
</tbody>
</table>

*Note. R² = .12 for Step 1 (p = .001); ΔR² = .004 for Step 2; ΔR² = .03 for Step 3; ΔR² = .01 for Step 4. **p < .01. CARE= Cognitive Appraisal of Risky Events Questionnaire-Expected Involvement; PANAS=Positive Affect Negative Affect Schedule.*
Table 6

Summary of Hierarchical Regression Analysis
Of Cognitive Variables and CARE-EI Scores for Females (N = 46)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>PANAS</td>
<td>.48</td>
<td>.45</td>
<td>.17</td>
</tr>
<tr>
<td>Gambling Task</td>
<td>.07</td>
<td>.12</td>
<td>.09</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>1.07</td>
<td>12.72</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note. R² = .03 for Step 1 (p = .22); ΔR² = .007 for Step 2 (p = .58); ΔR² = .00 for Step 3 (p = .93). CARE= Cognitive Appraisal of Risky Events Questionnaire-Expected Involvement; PANAS=Positive Affect Negative Affect Schedule.

Table 7

Summary of Hierarchical Regression Analysis
Of Cognitive Variables and CARE-EI Scores for Males (N = 44)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>PANAS</td>
<td>.31</td>
<td>.58</td>
<td>.08</td>
</tr>
<tr>
<td>Gambling Task</td>
<td>-.33</td>
<td>.14</td>
<td>-.36*</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>33.78</td>
<td>18.27</td>
<td>.26</td>
</tr>
</tbody>
</table>

Note. R² = .01 for Step 1 (p = .94); ΔR² = .11 for Step 2, (p = .03); ΔR² = .07 for Step 3, (p = .07). *p < .05. CARE= Cognitive Appraisal of Risky Events Questionnaire-Expected Involvement; PANAS=Positive Affect Negative Affect Schedule.

Exploratory Analyses

Results of the proposed analyses supported the hypothesis that a relationship exists between the behavioral activation/inhibition systems and Gambling Task performance. In order to expand on the BAS/BIS findings, a series of additional exploratory analyses were performed. To explore for a possible relationship between
psychophysiological responses during Gambling Task performance and BAS/BIS ratio, a one-way analysis of covariance of the three BAS/BIS ratios on the (log of) mean SCL difference score for the 10 forced trials of the gambling task was performed, with PANAS score as a covariate. No relationship was found between BAS/BIS ratio and (log of) mean SCL difference scores, \(F(2, 79) = .89, p = .42\). BAS/BIS ratio was also examined to determine if it was related to other executive function variables. Due to problems with the other cognitive variables, it was determined that only the transformed Perseverative Error variable was suitable for analysis. A one-way analysis of covariance of the three BAS/BIS ratios on transformed Persevered Errors was performed, with PANAS score as a covariate. No relationship was found between BAS/BIS ratio and transformed Perseverative Errors, \(F(2, 86) = .69, p = .50\).

Table 8

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Top 1/3</td>
<td>28</td>
<td>-7.47</td>
<td>5.34</td>
</tr>
<tr>
<td>2) Middle 1/3</td>
<td>34</td>
<td>26.89</td>
<td>4.72</td>
</tr>
<tr>
<td>3) Bottom 1/3</td>
<td>28</td>
<td>23.31</td>
<td>5.34</td>
</tr>
</tbody>
</table>

*Note. Significant difference between 3 and 1 (\(p < .01\)), and 2 and 1 (\(p < .001\)). BAS=Behavioral Activation System; BIS=Behavioral Inhibition System.*

The relationship between BAS/BIS ratio and Gambling Task performance was also further explored. Previous studies by Bechara and colleagues determined that a net Gambling Task score of <10 represents the threshold for impaired performance based on
the data from individuals with ventromedial lesions (Bechara et al., 2002). Using this
cutoff, 44.4% of individuals in the full sample fell below the cutoff. For the three
BAS/BIS ratio groups, it was found that 60.71% of the individuals in the top third of
BAS to BIS ratio, 32.35% of individuals in the middle third, and 42.86% in the bottom
third fell below the cutoff. Chi-square analyses approached significance, \( \chi^2(1) = 5.05, p = .08 \).

Table 9

Log of Mean Disadvantageous and Advantageous SCL Difference Scores Based on
Gambling Task Performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 1/3</td>
<td>28</td>
<td>.16</td>
<td>.04</td>
</tr>
<tr>
<td>Middle 1/3</td>
<td>28</td>
<td>.15</td>
<td>.03</td>
</tr>
<tr>
<td>Bottom 1/3</td>
<td>30</td>
<td>.14</td>
<td>.04</td>
</tr>
</tbody>
</table>

*Note.* SCL = Skin Conductance Level.

Table 10

Log of Mean Disadvantageous and Advantageous SCL Difference Scores for the 10
Forced Trials

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 1/3</td>
<td>27</td>
<td>.17</td>
<td>.05</td>
</tr>
<tr>
<td>Middle 1/3</td>
<td>27</td>
<td>.18</td>
<td>.05</td>
</tr>
<tr>
<td>Bottom 1/3</td>
<td>29</td>
<td>.19</td>
<td>.05</td>
</tr>
</tbody>
</table>

*Note.* SCL = Skin Conductance Level.
To further explore Gambling Task performance based on BAS/BIS ratio, Gambling Task performance was divided into five blocks of 20 card selections to examine changes in performance over time. For each block, the number of disadvantageous selections was subtracted from the number of advantageous selections, creating a difference score with a higher score representing better performance. Performance across blocks was examined using a repeated measure analysis of covariance, with the five blocks as the within-subjects factor and the three levels of BAS/BIS ratio (top third, middle third, bottom third) as the between-subjects factor. To control for affect, PANAS score was entered as a covariate. The assumption of sphericity was not met (Mauchly’s $W = .49, p < .001$), so the degrees of freedom for tests of within-subject effects were adjusted using the Greenhouse-Geisser $F$ test. Results revealed a significant main effect for block, $F(2.86, 245.78) = 2.91, p = .04$; BAS/BIS ratio, $F(2, 86) = 12.72, p < .001$; PANAS, $F(1, 86) = 13.39, p < .001$; and a significant BAS/BIS ratio $X$ block interaction, $F(5.72, 245.78) = 3.9, p < .01$. There was no significant PANAS $X$ block interaction, $F(2.86, 245.78) = 2.05, p = .11$.

The interaction between BAS/BIS ratio and Gambling Task block is plotted in Figure 5. It can be seen that the middle third and bottom third groups of BAS to BIS ratio increase in advantageous selection, or remain at the same level, in each successive block with the exception of block four for the middle third group. By contrast, the top third BAS to BIS ratio group shows less gain across successive blocks.
To further explore the interaction between BAS/BIS ratio and Gambling Task block, follow-up one-way ANCOVAs, controlling for PANAS, were performed. Results revealed significant differences between the three BAS/BIS ratio groups in block two (selections 21 to 40), $F(2, 86) = 5.33, p < .01$, block three (selections 41 to 60), $F(2, 86) = 10.94, p < .001$, block four (selection 61 to 80), $F(2, 86) = 8.94, p < .001$, and block five (selection 81 to 100), $F(2, 86) = 12.68, p < .001$. Post hoc analyses, using the least significant difference procedure, revealed significant differences between the top third BAS/BIS ratio group, and the middle third as well as the bottom third for each block with
the exception of block one. No significant differences were found between the middle third and bottom third BIS/BAS ratio groups in any block. Summary of the post-hoc analyses is presented in Table 11.

Table 11

<table>
<thead>
<tr>
<th>BAS/BIS Ratio</th>
<th>Block 1 (1-20)</th>
<th>Block 2 (21-40)</th>
<th>Block 3 (41-60)</th>
<th>Block 4 (61-80)</th>
<th>Block 5 (81-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Third -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Third</td>
<td>.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top Third -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom third</td>
<td>.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Third -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom third</td>
<td>.18</td>
<td>1.11</td>
<td>1.96</td>
<td>2.49</td>
<td>2.17</td>
</tr>
</tbody>
</table>

Note. * p < .05. ** p < .01. BIS = behavioral inhibition system, BAS = behavioral activation system.

A final analysis was conducted to explore the relationship between BAS/BIS ratio and CARE-EI scores. The mean CARE scores for each BAS/BIS ratio group are presented in Table 12. A one-way analysis of covariance of the three BAS/BIS ratio groups on CARE-EI scores was conducted, controlling for gender. Differences in CARE-EI scores between the three BAS/BIS ratios approached significance, \( F(2, 86) = 2.85, p = .06 \). A significant relationship was found for the covariate Gender \( (p < .01) \). Post hoc analysis, using the least significant difference procedure, found a significant difference between the top third and bottom third of BAS to BIS ratio \( (p = .02) \), indicating that individuals in the highest BAS to BIS ratio group reported significantly higher expected
involvement in risk taking behaviors compared to individuals in the lowest BAS to BIS ratio group. To examine gender groups independently, a correlational analysis was performed for BAS/BIS ratio and CARE-EI score for females and males separately. Significant positive correlation were found for females, $r = .33, p = .01$ (one-tailed); and males, $r = .27, p = .04$ (one-tailed).

Table 12

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Top 1/3</td>
<td>28</td>
<td>94.86</td>
<td>33.99</td>
</tr>
<tr>
<td>2) Middle 1/3</td>
<td>34</td>
<td>83.65</td>
<td>23.11</td>
</tr>
<tr>
<td>3) Bottom 1/3</td>
<td>28</td>
<td>73.57</td>
<td>25.08</td>
</tr>
</tbody>
</table>

*Note. Significant difference between 3 and 1 ($p < .05$). BAS=behavioral activation system; BIS=Behavioral inhibition system; CARE=Cognitive Appraisal of Risky Events Questionnaire.*

Discussion

Risk-taking behavior results in a variety of public health problems, including drug and alcohol abuse, head injury, accidental death, heart disease, and cancer, to name a few. Traditional decision-making theories based on rationality have failed to explain and predict such behaviors. The Gambling Task is a decision-making task that has shown utility as a measure of decision-making deficits in a variety of populations that engage in risk-taking behaviors. The present study had multiple aims covering two broad categories. First, this study sought to explore risk-taking in the general population, with
respect to cognitive ability in the executive functions domain that may be related to such behaviors. Second, this study explored individual differences in Gambling Task performance, which past research has suggested relates to decision-making deficits in risk-takers, and explored dispositional and cognitive aspects of Gambling Task performance.

**Objective 1: Executive-Function Variables Associated with Risk-Taking Behavior**

The current study provided some support for a relationship between executive function variables and self-report of expected involvement in risk-taking behaviors. Gender differences accounted for a significant amount of variance, with males reporting a significantly higher level of expected participation in risk-taking behaviors. None of the other variables approached significance in the main analysis. Due to the strong relationship between gender and risk-taking, males and females were analyzed separately. This analysis found that a significant relationship did not exist between executive function variables and self-report of expected involvement in risk-taking behaviors for females; however, for males the Gambling Task did account for a significant amount of variance and Perseverative Errors approached significance. These findings suggest that, at least for males, there is a relationship between executive function skills and risk-taking behavior.

There are several explanations as to why a relationship was not found between executive function variables and risk-taking behavior in the main analysis or for females. With regard to the female only analysis, there is the possibility that a stronger relationship does not exist for females in the population sampled. Also, the females sampled for this study reported significantly less expected participation in risk-taking
behavior than males. There is also the potential for gender differences in risk-taking as a result of socialization. The behaviors measured by the CARE may be more typical of males or, at the very least, females may be more reluctant to report them. The sample may not have included enough females who were at the higher end of the risk-taking spectrum. There is also the likelihood that that factors involved in risk-taking behavior differ based on gender. For example, for males executive functions may be a major factor and for females other variables may be more relevant. Another possible explanation for the lack of findings in the full sample analysis is that participants in the present study were too homogenous in their participation in risk-taking behaviors. This possibility can be ruled out since the CARE score demonstrated considerable variability in the overall sample. In addition, there is always the possibility with self-report that individuals are not fully disclosing the extent of their involvement in certain behaviors that are considered undesirable. Although “expected future involvement” was used as a way of increasing the likelihood of honest disclosure, this method may not be any more effective than asking for participants’ self-report of past involvement and may result in a similar conservative response bias.

In exploring the relationship between executive functioning and risk-taking behaviors in the general population, the major obstacle is likely the manner in which risk-taking behavior is measured. The CARE appears to have some potential for this purpose. However, in future studies, other methods should be considered or used in addition to the CARE. It is recommended that future studies explore more objective methods of determining risk-taking behavior in undergraduates; for example, making an effort to recruit students who had some disciplinary action taken against them, or students who
have been charged with driving under the influence. This would ensure inclusion of individuals at the more extreme end of risk-taking behavior.

**Objective 2: Relationship Between Executive Function Measures**

Consistent with the research of Bechara and colleagues, this study found no relationship between other measures of executive function (Perseverative Errors) and Gambling Task performance. This is consistent with the idea that decision-making ability as measured by the Gambling Task cannot be attributed to other executive functions. Unfortunately, only one executive function variable was used in the analysis because of psychometric problems with the other measures; thus nothing can be concluded about the relationship between impulsivity and Gambling Task performance since the Go/No Go task was not used in the analysis. Future research should include measures of impulsivity that are more sensitive to individual differences in the general population.

**Objective 3: The Relationship Between Dispositional Variables and Gambling Task Performance**

The present study utilized Gray’s theory of behavioral activation and behavioral inhibition systems (BIS/BAS) as the basis for a dispositional variable possibly related to Gambling Task performance. Results supported the hypothesized relationship between normal range variability in BIS/BAS tendencies and Gambling Task performance. Individuals with a higher BIS to BAS ratio, as well as those with a balance between the two systems, performed significantly better on the Gambling Task than individuals with a higher BAS to BIS ratio. Furthermore, the group with the highest BAS to BIS ratio had the highest percentage (60.71%) of individuals who showed performance in the range of ventromedial prefrontal lesion patients (net score of <10). This finding suggests that
individuals who exhibit high BAS traits are sensitive to rewards and relatively insensitive to potential and experienced punishment. On the Gambling Task, this translates into a preference for the disadvantageous deck and their high immediate payoff. Furthermore, their insensitivity to punishment may prevent them from moving towards the advantageous decks over successive trials. This was confirmed in an exploratory analysis in which the high BAS group continued to select disadvantageously for the duration of the task. In fact, when Gambling Task performance was broken down into five blocks of 20 selections each, the high BAS group was outperformed on every block except the first. This is consistent with a previous study using the same self-report measure of BIS/BAS functioning and comparing a high BIS low BAS group and a low BIS high BAS group (van Honk et al, 2002). In addition, the current study found that the high BAS group had a significantly higher mean CARE score than the high BIS group.

The relationship between BIS/BAS, the CARE, and the Gambling Task indicates a dispositional component to decision-making and risk-taking behavior. These results are consistent with the conceptualization of the BIS/BAS systems, and the current study indirectly connects the BIS/BAS system with individual differences in prefrontal lobe functioning. This connection is in line with Gray’s hypothesized biological basis for the BIS/BAS system (Gray, 1987), and he has gone as far as hypothesizing that the prefrontal cortex has some involvement in the BIS system specifically (Gray, 1987). The hypothesized dispositional component of decision-making and risk-taking that is related to prefrontal lobe functioning is also consistent with the well-documented personality changes that are the hallmark of damage to the prefrontal lobes. It is possible that injuries to the ventromedial prefrontal cortex disrupt the BIS and allow the BAS to go unchecked.
This conceptualization follows the behavioral observation of such patients; however, more research is needed to explore this relationship. Future studies using the Gambling Task should consider measuring BIS/BAS balance. Carver & White’s BIS/BAS scale was employed in this study and the results presented here provide evidence for its continued use as a measure of BIS/BAS balance. In addition, affect has been considered by some theorists to represent trait dimensions of emotionality (Tellegen, 1985). In this study affect demonstrated a relationship to Gambling Task performance and somatic markers. Given that the measure of affect used in this study, the PANAS, has demonstrated temporal stability (Watson et al., 1988), it may be considered a dispositional variable and used for this purpose in other studies. Also, the PANAS score used in this study combined both positive and negative affect. Future studies should explore positive affect and negative affects as independent factors in order to determine whether they are both relevant to Gambling Task performance or if the findings in this study represents the contribution of one aspect of affect and not the other.

*Objective 4: Exploration of the Somatic Marker Hypothesis*

The current study’s findings provided some evidence for the somatic marker hypothesis, as well as for an alternative method for collecting physiological data with the Gambling Task. A significant difference was found when comparing anticipatory responses for advantageous and disadvantageous selections for both the standard Gambling Task administration and the ten forced-choice trials when using the full sample. These results support the findings of Bechara and colleagues. The ten forced choice trials had a greater difference between disadvantageous and advantageous mean anticipatory SCL than the standard administration, although it is not unusual for there to
be an increase in SCL level over time in a given recording period. No significant relationships were found between Gambling Task performance and SCL, or BAS/BIS ratio and SCL. However, a trend was found when comparing the top third of performers on the Gambling Task to the bottom third of performers on the ten forced trials, suggesting the better performers had greater mean SCL difference scores. Also, a significant relationship was found between affect and SCL difference scores for the ten forced trials indicating positive affect was associated with greater SCL difference scores. It is speculated that forcing individuals to choose from a deck that they know to be risky activates the somatic marker. In the case of the standard task, participants have the opportunity to continually avoid such selections. They may sample from these decks later; however, their autonomic response may not be as strong since they are willing, in those situations, to face the risk. This presents a different decision-making paradigm compared to their early exposure to these decks when they are getting a “sense” of which decks are good and bad. It should also be pointed out that some individuals only choose from the disadvantageous decks in the first twenty or so selections and then never return to those decks. Forcing them to make disadvantageous selections later (as done in the present study with the final forced trials) may result in an activation of a somatic marker that was avoided for the majority of the standard administration. It is recommended that future studies utilize the procedure presented in the current study, in an attempt to replicate these results. This method not only has the potential to get more consistent data, but it also required less work from the experimenter in the data reduction phase and could lead to more researchers using psychophysiological variables when doing Gambling Task research.
Objective 5: Gender Differences on the CARE, Gambling Task, and BIS/BAS Scale

Although the CARE was developed and validated on an undergraduate population, there was no reported data regarding gender differences. Results of this study found a significant difference between the CARE scores of women and men, with males having significantly higher scores. This difference is consistent with other research examining gender differences in risk-taking behavior. For example, epidemiological surveys consistently find that males are much more likely to abuse alcohol at every age (Grant, 1997; Helzer, Canino, Yeh, Bland, Lee, Hwu & Newman, 1988). Furthermore, gender differences were found for the BIS/BAS scale, with males having a higher BAS to BIS ratio compared to females. No gender differences were found for Gambling Task performance. Future studies may want to consider doing individual analyses for men and women in order to eliminate the gender influence in studies of risk-taking behavior.

Components of Risk-Taking Behavior

The results of this study require a reexamination of disposition, cognitive (executive) functions, and physical (autonomic) response and their hypothesized relationship to risk-taking behaviors. Figure 6 represents the hypothesized relationship between disposition, physical (autonomic) response, cognitive (executive) functions, and risk-taking behavior.

This figure indicates that disposition now includes affect and behavioral activation/behavioral inhibition system ratio (BAS/BIS) as important components. An arrow is moving from risk-taking behavior to disposition since it is likely that a reciprocal relationship exists between disposition and experience where level of reward and punishment experienced are influenced by disposition, which then influences subsequent
experience. From a decision making perspective, a higher BAS to BIS ratio may lead the individual to approach in a “risky” situation where both positive and negative outcomes are possible. Their disposition leads them to be more influenced by the positive outcome rather than negative outcome if both are experienced. The result is a greater likelihood to approach the next time the situation is encountered even if the negative outcome has been experienced. Disposition is speculated to directly influence the individual’s likelihood of participating in risk-taking behavior and also influence cognitive (executive) functions both directly, as well as through physical (autonomic) responses. Finally, cognitive (executive) functions, are believed to have a direct relationship to risk-taking behavior. They are also potentially influenced by disposition through physical (autonomic) responses. Based on the results of this study, the cognitive (executive) functions that are most influenced by disposition and physical (autonomic) response are those involving the ventromedial prefrontal cortex.

Future studies may consider using this speculative model as a starting point in studying the relationship between these factors and risk-taking behaviors. These findings are consistent with the view of the prefrontal lobes as the center of personality and also make a distinction between what are more traditional cognitive (executive) skills and cognitive functions that involve, and are influenced by, broader components such as disposition, affect, and autonomic responses. Future studies should continue exploring the relationship between somatic markers and disposition variables since this represents a conceptual pathway where disposition has a direct impact on ventromedial prefrontal-based cognitive functions.
Strengths and Limitations of the Present Study

While the present study failed to find a significant relationship between executive function and risk-taking behaviors in the main analysis, results from exploratory analyses indicate that future studies should continue to explore the relationship between the Gambling Task and risk-taking behavior. This relationship should be examined in a more heterogeneous population with regard to risk-taking behavior. The current study used a relatively homogenous sample (undergraduates at a mid-sized Midwestern university) and this is a major limitation. Another recommendation is based on recent findings using the Gambling Task with different clinical populations, some of who engage in risky or impulsive behaviors. New research has expanded the literature on the relationship between Gambling Task performance and different types of “risky” behaviors. For example, a recent study found that individuals who have attempted suicide performed worse than normal controls on the Gambling Task (Jollant et al., 2005). Another study found a significant relationship between body mass index (BMI) and Gambling Task performance (Levitan, Muglia, Bewell & Kennedy, 2004). In fact, individuals at the high end of BMI performed worse on this task than substance dependant individuals in previous studies (Levitan et al., 2004). Other studies suggest that poor Gambling Task performance is found in several other clinical populations. For example, individuals who are obese, individuals who have attempted suicide, individuals who suffer from chronic pain, and individuals who have been diagnosed with schizophrenia all show performance deficits on this task (Apkarian, Sosa, Krauss, Thomas, Fredrickson, Levy, Harden, & Chialvo, 2004; Shurman, Horan & Nuechterlein, 2005). Future studies should continue studying different clinical populations and use additional variables in studies to better
understand the nature of the performance deficit and its potential relationship to risk taking behavior.

Figure 6. The Components of Risk-Taking Behavior

A limitation of the current study, as well as many other studies using the Gambling Task, is the use of an only an overall score as a measure of performance. This method has become the most popular method of analyzing Gambling Task performance; however, it fails to provide any information as to why an individual performed poorly. Recently, researchers have started using cognitive modeling (Busmeyer et al., 2001) to analyze Gambling Task data in new ways that provide more information regarding specific cognitive factors involved in poor performance. Given that the findings of this study suggest that somatic markers may not be a central factor of Gambling Task
performance, these specific cognitive factors should be explored. Future studies using the Gambling Task should include these methods and compare them with other variables (dispositional, psychophysiological) to better understand the different factors involved in Gambling Task performance. These purpose of these future studies may be to build a model of the variables involved in Gambling Task performance.

A strength of the present study was the inclusion of a measure of affect as a potential covariate. Prior studies using the Gambling Task have failed to control for this relationship. It follows from both decision-making theory and the somatic marker hypothesis that affect may be a factor in Gambling Task performance. The relationship found in the current study suggests that negative affect could lead to poor Gambling Task performance and is consistent with the existing literature that has found individuals with a positive mood state to be more risk aversive and self-protecting in decision-making situation (Nygren, 1998; Arkes et al., 1988). As a result mental health factors, in particular depression, could account for poor Gambling Task performance. This may be particularly problematic in several of the populations regularly studied using the Gambling Task (i.e., neurological and substance dependent populations) where negative affect is common. Thus, future studies using the Gambling Task should control for affect.

Conclusion

While the present study failed to fully confirm the hypothesis that a significant relationship exists between executive functions and risk-taking behavior in the general population, the results warrant that future studies continue exploring this relationship,
especially in individuals who are more active with regard to these behaviors. The results of the current study suggest the Gambling Task is a potentially valuable tool for understanding the complex interaction between executive function, dispositional, and affective variables. This study found that disposition (i.e., BIS/BAS) is an important variable related to Gambling Task performance. Unfortunately, since a clear relationship between Gambling Task performance and risk-taking behavior was not found in the full sample, these findings cannot be generalized to risk-taking. However, this study did find evidence that the Gambling Task and BAS tendencies are related to such behaviors in males. The findings of the current study, as well as other studies reviewed here, indicate that the Gambling Task may still hold promise as a useful experimental method for determining the complex interaction of variables involved in risk-taking behavior.


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*, 215-225.


Appendix A

Experimental Sign-Up

Neuropsychological correlates of risk-taking behavior in an undergraduate population.

This study involves completing two questionnaires and several tests of thinking and problem solving. Electrodermal activity (amount of perspiration on the fingers) will be recorded during one of the problem-solving tasks. This experiment will last 50 to 90 minutes and you will receive 2 credits. Select a time slot and sign your name. The experiment will take place at the Clinical Neuropsychology Research Laboratory on the 3\textsuperscript{rd} floor of Porter Hall in room 324.
### Appendix B

**CARE**

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

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

22. Smoking Marijuana
   Not at all likely       Extremely Likely
   1               2                    3       4     5             6     7

23. Sex with multiple partners
   Not at all likely       Extremely Likely
   1               2                    3       4     5             6     7

24. Snow or water-skiing
   Not at all likely       Extremely Likely
   1               2                    3       4     5             6     7

25. Mixing drugs and alcohol
   Not at all likely       Extremely Likely
   1               2                    3       4     5             6     7

26. Getting into a fight or argument
   Not at all likely       Extremely Likely
   1               2                    3       4     5             6     7

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

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

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

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

BIS/BAS

Participant Number ________________

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

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

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

1. If I think something unpleasant is going to happen I usually get pretty “worked up.” ___
2. I worry about making mistakes. ___
3. Criticism or scolding hurts me quite a bit. ______
4. I feel pretty worried or upset when I think or know somebody is angry at me. ___
5. Even if something bad is about to happen to me, I rarely experience fear or nervousness. ___
6. I feel worried when I think I have done poorly at something. ___
7. I have very few fears compared to my friends. ___
8. When I get something I want, I feel excited and energized. ______
9. When I am doing well at something, I love to keep at it. ______
10. When good things happen to me, it affects me strongly. ______
11. It would excite me to win a contest. ____
12. When I see an opportunity for something I like, I get excited right away. ______
13. When I want something, I usually go all out to get it. ___
14. I go out of my way to get things I want. ______
15. If I see a chance to get something I want, I move on it right away. _____
16. When I go after something I use a “no holds barred” approach. ______
17. I will often do things for no other reason than that they might be fun. ______
18. I crave excitement and new sensations. ______
19. I’m always willing to try something new if I think it will be fun. _____
20. I often act on the spur of the moment. ______
Appendix D

PANAS

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now, that is, at the present moment. Use the following scale to record your answers.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>very slightly or not at all</td>
<td>a little</td>
<td>moderately</td>
<td>quite a bit</td>
<td>extremely</td>
</tr>
</tbody>
</table>

_____ interested
_____ distressed
_____ excited
_____ upset
_____ strong
_____ guilty
_____ scared
_____ hostile
_____ enthusiastic
_____ proud

_____ irritable
_____ alert
_____ ashamed
_____ inspired
_____ nervous
_____ determined
_____ attentive
_____ jittery
_____ active
_____ afraid
Appendix E

Ohio University Consent Form

Title of Research: Neuropsychological correlates of risk-taking behavior in an undergraduate population

Principal Investigator: John Tsanadis, M.S. and Julie Suhr, Ph.D.

Department: Psychology

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

**Explanation of Study**

The purpose of this study is to examine the relationship between certain aspects of cognitive functioning and involvement in risk-taking behaviors. You will complete a self-report measure of expected involvement in a variety of risk-taking behaviors. You will also complete a self-report measure of your current mood and personality traits. These measures will be followed by a series of thinking and problem-solving tasks, one of which is computerized. During the final task electrodes will be attached on two of your fingers using velcro straps to record your electrodermal activity (amount of perspiration on your finger) during the task. This procedure does not involve any discomfort. This experiment is expected to take between 70-90 minutes.

**Risks and Discomforts**

You may feel uncomfortable with some of the questions on one of the self-report measures, but identifying information is not attached to the questionnaire so there is no way to link your answers to you.

**Benefits**

The main benefit of this study is that you will get first-hand experience of psychological testing. In addition, this study has the potential to increase our knowledge of the factors associated with risk-taking behaviors. This could lead to better interventions for treating and preventing a variety of problems associated with risk-taking behavior.
Confidentiality and Records

All records will be kept confidential. Once you provide consent you will be given a participant number and your name will not be associated with any of your data. Once you leave the lab there will be no way to identify you from your data. All data collected will be kept in a locked cabinet in the research laboratory of Dr. Julie Suhr.

Compensation

You will receive two experimental credits for your participation.

Contact Information

If you have any questions regarding this study, please contact Julie Suhr, Ph.D (suhr@ohio.edu/593-1091).

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature________________________________________________________ Date__________

Printed Name______________________________________________
Appendix F

Demographic Questionnaire

Id _______________________ Age: _____  Gender:  male    female

Current level of education:  freshman    sophomore    junior    senior

Handedness  left    right

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

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

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

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

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

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

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

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

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

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

Debriefing Form

The purpose of this study is to explore the relationship between certain aspects of cognitive functioning and risk-taking behavior. You completed a self-report measure of the likelihood you will engage in a variety of risk-taking behaviors and several tests of cognitive functioning. The goal of this study is to examine the role of the cognitive factors on an individual’s involvement in risk-taking behaviors. Since other factors can be related to an individual’s involvement in risk-taking behavior, we had you complete measures of your current mood, and personality variables so we can control for them in our analysis. We are testing the hypothesis that risk-taking behavior is related to an area of cognitive functioning called executive functions. The cognitive tests you completed are specific to executive functions. Executive functions are directly involved in decision-making and utilize a variety of information in the process of making a decision. One source of information may be feelings. As a result, we are testing this by recording psychophysiological responses (the electrodes we placed on your fingers) during a decision-making task (the gambling game you completed).

During this study you answered several questions regarding specific behaviors, and rated how likely you are to participate in them. If you feel that you have a problem related to any of these behaviors such as drug and alcohol use, you may want to talk about it with a professional. There are centers at the University and in the community that you can contact and meet with a professional and discuss your concerns. Please do not hesitate to contact either of the following:

**Ohio University Counseling and Psychological Services-593-1616**

**Health Recovery Services–592-6720**