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Adolescent Decision Making and Risk Behavior: A Neurobiological Approach

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ADOLESCENT DECISION MAKING AND RISK BEHAVIOR:

A NEUROBIOLOGICAL APPROACH

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In this study, the neurobiological theory of adolescent decision making and risk taking and the dual-process decision making theory were tested in a sample of college students. Participants responded to questions in a survey about decision making style, socio-emotional processes, cognitive control processes, and deviant peers. The goals of the research were to test the relation between decision making processes (intuitive and deliberative) and risk behaviors, to test the potential overlap between intuitive and deliberative decision making as described in the more traditional dual-process models and the socio-emotional and cognitive control systems of the neurobiological model, and to extend the neurobiological model by examining the role of individual and social contextual factors in risk behavior. This research is intended to strengthen, expand, and improve our existing knowledge of youth decision making and risk behavior. Results showed that cognitive control processes and deliberative decision making were related to each other whereas socio-emotional processes and intuitive decision making were not. Deliberative decision making was related to risk behaviors whereas intuitive decision making was not. Finally, self-regulation and deviant peers moderated the relations between some of the socio-emotional or cognitive control constructs and risk behavior. Results are discussed in terms of their theoretical and practical implications as well as future directions for research.

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CHAPTER 1: INTRODUCTION

Adolescents are more likely than older or younger individuals to engage in risky behaviors, such as drinking alcohol, taking illegal drugs, having unprotected sex, engaging in delinquent activity, and driving recklessly (Arnett, 2000). Because these behaviors can result in injury, arrest, pregnancy, or death, an important task for developmental researchers is to understand the mechanisms that contribute to these outcomes, which may include biological, cognitive, and psychosocial factors (Kelley, Schochet, & Landrey, 2004). One crucial factor is likely to be the decision making process that adolescents use when opportunities for risk behavior arise. Although research on predictors and correlates of risk behavior is plentiful (see Jessor, 1998; Rivara, Park, & Irwin, 2009), surprisingly little research has addressed the decision making process adolescents employ when faced with the opportunity for risk behavior in the real world. The primary goal of this study is to better understand how adolescents make decisions to engage in risk behavior and to determine some factors that affect the decision making process.

One promising theoretical model for understanding adolescent risk behavior is a neurobiological model which has been developed to explain why adolescents are particularly at increased risk of making poor decisions to engage in risk behavior (Steinberg, 2007; Steinberg, 2008). According to this model, there are two brain systems developing throughout adolescence which are directly related to risk behavior. The first brain system is the socio-emotional system which is sensitive to social and emotional stimuli and has to do with an increase in sensation seeking behaviors that have been shown to peak in early-to-middle adolescence (Steinberg, Albert, Banich, Cauffman,

Graham, & Woolard, 2008). The development of the socio-emotional system is hypothesized to be related to remodeling of the dopaminergic system in the brain, affecting attraction to rewarding and novel stimuli and thus resulting in an increase in sensation seeking behavior (Steinberg, 2008). The other system of the neurobiological model is the cognitive control system which involves controlling impulses, planning ahead, and other executive functions. This system is thought to develop linearly throughout adolescence and is hypothesized to be related to the development of the prefrontal cortex and increased connectivity between cortical and subcortical regions (Steinberg, 2008). Therefore, risk behavior is thought to occur in early to mid adolescence because the socio-emotional system is highly developed and potent whereas the cognitive control system is not yet sufficiently developed to control impulses of the socio-emotional system.

There are several advantages of this dual-system neurobiological model over traditional models of decision making. First, it is developmental and explains *why* risk behavior increases in adolescence and tends to decrease in adulthood. Furthermore, the neurobiological model incorporates multiple aspects of adolescent development and risk behavior, involving social, emotional, neurological, and cognitive development. Specifically, the model addresses changes in salience of peers, emotional volatility often experienced in adolescence, brain changes, and the development of increased cognitive competency. However, there are also limitations of this model. One major drawback is that the model does not account for individual differences in risk behavior other than those associated with age. Much previous research on adolescent risk behavior has found several individual and social differences that contribute to risk behavior, including having

delinquent friends, poor parenting practices, low self-regulation, and environmental context to name a few (Chassin, Hussong, Barrera, Molina, Trim, & Ritter, 2004; Farrington, 2004). The neurobiological model has thus far failed to take into account potential individual differences in risk behavior. Therefore, a second goal of the proposed study was to extend this developmental model by examining temperamental and social differences in decision making and risk behavior.

A third goal was to examine the relationship between decision making and constructs that characterize the socio-emotional and cognitive control systems of the neurobiological model. Contemporary models of adolescent decision making (dual process models) typically involve two processes. The first is an intuitive or experiential process, in which decisions are made quickly and without much conscious thought. This is the process by which most decisions are made. The second process is an analytical or deliberative process in which decisions are made consciously and with effort (see Kahneman, 2003; Klaczynski, 2005). Although studied in the lab, these two processes have rarely been examined in regard to their relation to adolescent risk behavior in the real world. The proposed research will test this association and also examine potential overlap between the constructs in more traditional conceptualizations of dual process decision making in adolescence and the constructs involved in the neurobiological model.

In summary, there were three primary goals of the research. First, the relation between decision making processes (intuitive and deliberative) and risk behaviors were examined. Second, the potential overlap between intuitive and deliberative decision making as described in the more traditional dual-process models and the socioemotional and cognitive control systems of the neurobiological model was examined. Finally, the

proposed research sought to extend the neurobiological model by examining the role of individual and social factors in risk behavior. This research was intended to strengthen, expand, and improve our existing knowledge of adolescent decision making and risk behavior.

In the following sections, adolescent risk behavior and its correlates are discussed, followed by a detailed description of dual-process decision making models. Then the neurobiological model, the basis of the proposed research, is presented and explained along with aspects of adolescent brain development that are integral to the neurobiological model. Finally, the individual and social variables that may affect (moderate) the relation between decision making and risk behavior are discussed.

Adolescent and Young Adult Risk Behavior

Considerable attention has recently been given to the "paradox of adolescent health" (Dahl, 2004). Adolescence is a life stage during which individuals are generally at their strongest and healthiest, yet, compared to other life stages, they have increased morbidity and mortality rates from preventable causes. One explanation of this paradox involves adolescents' propensity for risk-taking. Risk taking can be defined as engaging, often impulsively, in behaviors that are high in subjective desirability or excitement but which carry the potential for injury or loss (Geier, Terwilliger, Teslovich, Velanova, & Lunda, 2010). Adolescents and young adults are more likely than individuals at other life stages to engage in behaviors that involve risks, such as drinking alcohol, taking illegal drugs, having unprotected sex, engaging in delinquent activity, and reckless driving (Arnett, 2000). For the purposes of this study, risk behaviors include these activities

because they put one's health and safety in danger and tend to incite societal concern for the well-being of adolescents.

Prevalence and Costs of Adolescent Risk Behaviors

The costs of adolescent and young adult risk behavior are staggering. In 2009 in the United States, the majority of all deaths among youth aged 10-24 resulted from unnatural causes, often motor-vehicle crashes, which many times involve an intoxicated driver (CDC, 2010). In 2007, there were 3,365 fatal car accidents among individuals aged 16-24 involving an intoxicated driver (NHTSA, 2007). One study found that driving after drinking increased markedly from age 19 to age 21, presumably due to being able to legally drink in public (Beck, Kasperski, Caldelra, Vincent, O'Grady, & Arria, 2010). Drinking alcohol is relatively common among adolescents and young adults. Of the adolescents surveyed in grades 9-12, 72.5% indicated any lifetime alcohol use and about 24.2% engaged in current heavy episodic drinking (CDC, 2010). Over 40% of college students reported binge drinking in the last two weeks (although results vary widely across campuses; Johnston, O'Malley, Bachman, & Schulenberg, 2011). Drug and alcohol overdoses contribute to many adolescent deaths and hospitalizations. Furthermore, about 26% of high school students currently smoked cigarettes and the percentage of smokers increased into the 20s. Almost 20% of adolescents and 33% of college students had used marijuana in the last 30 days (CDC, 2010; Johnston et al., 2011). Among college students in particular, there is increased co-occurrence of drinking and risky sexual behavior (Cooper, 2002). Risky sexual behavior is also a prevalent problem among young people. In 2009, there were approximately 9.1 million cases of

sexually transmitted diseases among youth aged 15-24 (CDC, 2010) and only 56.8% reported using contraception (American College Health Association, 2011).

There are societal costs involved in adolescent risk behaviors. For instance, in 2001 underage drinking incurred nearly $70 billion in medical, work loss, lost quality of life, and other resource costs (Miller, Levy, Spicer & Taylor, 2006) and teen pregnancy incurred over $9 billion in taxpayer's money (Hoffman, 2006). Furthermore, in 2005, there were 1.7 million juvenile delinquency cases handled in court (Sickmund, 2009). Understanding the decision-making processes contributing to these adolescent risk behaviors continues to be an important task for developmental researchers, with significant implications for practice and social policy.

Adolescence as a risky period. During adolescence, there are many changes, including physical, cognitive, emotional, and social changes, taking place within and among individuals that may be factors in adolescents' increased proclivity to take risks (Steinberg & Cauffman, 1999). For example, during adolescence, it is common to become more autonomous from parents, resulting in the opportunity to make more decisions independently (e.g., Steinberg, 2001; Byrnes, 2005). Adolescents also tend to become more influenced by peers and to care more about what their friends think (Prinstein, Borgers, & Spirito, 2001; Susman, Dent, McAdams, Stacy, Burton, & Flay, 1994). Indeed, most risk taking occurs in groups of peers, not independently (see Steinberg, 2007) suggesting that friends have a large influence over adolescents' decisions. Additionally, there are many brain changes occurring that may affect adolescents' decisions and behaviors (Steinberg, 2010a). Taken together, these changes,

which are common to adolescence, can lead to potentially dangerous decisions and behaviors.

An interesting question to pose is *why* do these changes take place in adolescence, especially since people take calculated risks throughout adulthood? Evolutionary theory may help to explain the purpose of some of the socio-emotional changes that accompany the biological changes. Rewards are objects or events that generate approach/consummatory behavior and involve positive or hedonic feelings. Rewards are therefore important for survival as they are integral for necessary behaviors, such as eating and reproduction (Schultz, 2010). A unique aspect of adolescence is attainment of sexual maturity. Evolutionary theory suggests that sexual promiscuity and competition peak in adolescence to help young people determine their own status and desirability as a mate and their preferences in a mate while practicing mate attraction tactics (Ellis et al., 2011; Weisfeld & Coleman, 2005). Ellis and colleagues (2011) assert that natural selection may favor strong emotional and behavioral responses to social stimuli during adolescence due to an increase in mating opportunities. For instance, engaging in daring yet dangerous activities in presence of members of the opposite sex may be construed as "showing-off" for potential mates.

Predictors of risk behavior often include social and cognitive factors. Often different types of risk behavior tend to have similar risk factors including social (poor parenting practices and deviant peer affiliations), cognitive (low IQ), temperamental (high impulsivity and poor self-regulation), and economic factors (low quality education and poor neighborhood quality) (see Farrington, 2004; Savin-Williams & Diamond, 2004; Chassin et al., 2004). Decision making has also been conceived as a potential

factor in risk behavior (Reyna & Farley, 2006). However, there is relatively little empirical evidence linking decision making to real world adolescent risk behavior.

Theories of Adolescent Decision Making

Many models of adolescent development have attempted to explain and describe risk behaviors, tapping into various possible contributing factors. There are also a number of models to explain human decision making, including dual-process models of decision making. This study focuses on dual-process models that concentrate on *adolescent* decision making and its relation to risk behavior. More specifically, the *neurobiological model* of adolescent decision making and risk taking is explained in detail. The present research is designed to strengthen the empirical evidence related to the neurobiological model, merge it with other conceptions of dual-process models, and address current shortcomings of the model.

Normative Decision Models

Normative models of decision making define how people should ideally reason, make judgments, and make decisions (Baron, 1994) based on the assumption that an optimal decision could be arrived at rationally and mathematically (Miller & Byrnes, 2001). Beyth-Marom and Fischhoff (1997) assert that one may be considered a competent decision maker if certain abilities are developed. The first ability is *complexity*, which is the ability to consider many elements simultaneously, systematically, and exhaustively, allowing integration of the diverse components of a decision. The second ability is *thinking about possibilities*, being able to think further into the future and consider long-term consequences. The third is *solving problems*, which is generating possible solutions, producing and evaluating decision options. The

fourth is *perspective-taking*, or relativistic thinking, referring to the ability to recognize others' perspectives, and considering and anticipating their actions and values. The final ability is being able to *reflect logically* on one's own decision making process. Following from these abilities, decision theory specifies five steps that should be involved in competent decision making: (1) Identify the possible options, (2) identify the possible consequences of each option, (3) evaluate the desirability of each consequence, (4) assess the likelihood of each consequence should each action be taken, and (5) combine everything according to a logically defensible "decision rule" (Beyth-Marom & Fischhoff, 1997; Baron, 1994; Beyth-Marom, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Furby & Beyth-Marom, 1992). This type of step approach not only describes competent decision making, but can also be a useful framework for analyzing developmental differences in decision making capacities (Byrnes, Miller, & Reynolds, 1999). For instance, some research has assessed age differences in the ability to identify options and consequences of certain behaviors (Halpern-Felsher & Cauffman, 2001). Studies have implied that faltering in one or more of the steps just outlined may lead an adolescent to make poor decisions, perhaps leading to engaging in health risk behaviors (Beyth-Marom, et al., 1993; Cauffman & Steinberg, 2000; Fried & Reppucci, 2001). Employing this type of step-wise model in decision making is thought to reduce impulsive behavior, which is antagonistic to competent decision making (Beyth-Marom, Fischhoff, Quadrel, & Furby, 1991; Galotti, 2001; Wills & Stoolmiller, 2002).

Another step-wise model of competent decision making is the self-regulation model developed by Byrnes and colleagues (2005; 2001; 1999). Competent decision making is defined as taking the necessary steps to accomplish a goal, which are: (1) Set a

goal, (2) Compile options for completing that goal, (3) Rank-order the options, and (4) Select the highest ranked alternative. This model also specifies that competent decision makers use logical strategies, such as gathering information about situations to help them make important decisions. For instance, feedback from previous decisions should be incorporated into one's existing knowledge and applied to future decisions. In a series of studies, Byrnes and colleagues (1999) found that, among adolescents, college students, and adults, college students learned to make better decisions than adolescents, and college students and adults also tended to improve their performance in a decision making task more than adolescents after receiving feedback (Byrnes et al., 1999). This suggests that relatively older people compared to adolescents are better at learning from their mistakes, incorporating new information, and making more accurate subsequent decisions, thus becoming more regulated decision makers. Although, another study showed that an adolescent's goals may be related to better decision making in certain cases (Miller & Byrnes, 2001). Adolescents who reported that social–relational goals were important to them also showed a higher level of decision making competence when faced with social-relational decisions and tended to report increased engagement in socially competent behavior. This provides support for the self-regulation model of decision making because it suggests that effective decision making is likely to occur when adolescents place importance on specific goals, and then engage in decisional processes that facilitate the attainment of those goals (Miller & Byrnes, 2001). Additionally, this line of research suggests that decision making ability is not necessarily a stable trait, but rather it may vary due to the domain of decision involved.

Competent decision making also includes the ability to recognize when a decision is important and deserves one's attention. An important decision is one that involves the potential for losses that are serious and difficult to rectify (Byrnes, 2005). When such a decision must be made, one should be more analytical. In contrast, when making an unimportant decision, one should conserve mental energy and rely on a more automatic process. In sum, the use of distinct strategies in decision making and having the knowledge of when to engage in these strategies are skills that are developed with age and can be in place by early adulthood (Byrnes, 2005). These skills may be related to the development of metacognition, which involves the ability the assess one's own reasoning, track the course of reasoning, and assess what one knows (Klaczynski, 2005). Competent decision makers have developed a repertoire of strategies to make decisions that will facilitate the attainment of goals (Byrnes, 2005). An important draw-back of the models just presented is that they imply that everyone eventually becomes a competent decision maker, capable of drawing on their goals when it is time to make an important decision. However, even adults sometimes make poor decisions.

Dual-Process Models

Decision making research in the past few decades has provided ample evidence that people rarely, if ever, make decisions perfectly rationally (Stanovich & West, 2000). For example, recent decision making research has found that people are not risk-neutral, meaning they interpret and respond to potential losses and gains differently (Polezzi, Sartori, Rumiati, Vidotto, & Daum, 2010). Also, Tversky and Kahneman (1981) demonstrated that people tend to violate assumptions of rationality by demonstrating the framing effect in which people make different choices depending on whether a problem

is worded in terms of losses or gains. Clearly, another explanation for decision making was needed. Dual-process models of decision making were developed as an alternative to normative models of decision making (e.g., Miller & Byrnes, 2001). Dual-process models are meant to describe how people actually make decisions, and these models recognize that most decisions are made outside of conscious thought whereas relatively few decisions are made with more deliberation and careful analysis (Klaczynski, 2005; Kahneman, 2003; Denes-Raj & Epstein, 1994).

The basic tenet of the dual-process models is that there are two processes of decision making: deliberative/analytical and intuitive/experiential. The deliberative process involves slower, more effortful, perhaps monitored, computational thinking and includes the ability to decontextualize reasoning from problem content. In other words a person who is being deliberative would not allow personal biases, prejudices, or framing to influence decisions. For this system to be activated, an individual needs to be motivated to make a decision carefullt and have a favorable disposition regarding analytical thought in that instance (Byrnes, 2005; Klaczynski, 2005). If one is going to make a decision using the analytical process, one must feel that the decision is important and deserves one's attention. The analytical system is also used for evaluating and justifying beliefs and decisions as well as setting goals, planning how to achieve them, and monitoring the progress towards the goals' achievement. The analytical system is similar to Byrnes' self-regulation model of decision making, but dual process models add a second and more common decision process.

The intuitive system is typically fast, automatic, effortless, sometimes emotionally charged, highly contextualized, operates in the periphery of awareness, and relies on

personal memories (Kahneman, 2003; Klaczynski, 2005). Decisions are made quickly and usually result in an intuition or "gut" feeling (Klaczynski, 2005). Procedural memories and decision heuristics play a role in intuitive processing. Procedural memories are memories of processes that one uses repeatedly (Fiske & Taylor, 2008). Decision heuristics are cognitive shortcuts used to make decisions quickly (Marsh, 2002). An example of a heuristic is the availability heuristic in which people think something is more common than it is because the information is more available. People who choose not to fly because they think plane crashes happen often even though flying is a relatively safe way to travel is a example of how the availability heuristic is used to make a decision. Heuristics are very influential in decision making, however, they are not always the deciding factor for similar decisions. New information about different outcomes, subtle differences in situations, and internal and external cues that are noticed by an individual may be assimilated into existing knowledge (Klaczynski, 2005), allowing new heuristics to develop and become available due to more experience with choices, outcomes, and consequences of decisions. The intuitive system is the default decision making system because it requires less cognitive capacity than effortful thinking (Kahneman, 2003; Klaczynski, 2005). It is also likely that evolutionary pressure favors the efficient processing of information (Schultz, 2010), allowing individuals to make snap decisions pertinent to survival (e.g., run away from the saber-tooth tiger). Although the intuitive system is the default, the deliberative system is theoretically able to override the prepotent responses of the intuitive system when the situation demands (Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Kahneman, 2003; Klaczynski, 2005; De Neys, 2006; Stanovich & West, 2000).

Klaczynski (2005) gives the underlying, pervasive assumptions of dual-process models: (a) intuitive and analytic processing can occur simultaneously, (b) they develop independently, (c) intuitive is the default; and (d) intuitive is predominant over analytic processing in a multitude of everyday situations. Neither process is superior, but rather, each may be appropriate for different decisions. Furthermore, either process can result in favorable or unfavorable outcomes. For instance, relying on the intuitive system may result in biases that could lead to incorrect conclusions, resulting in incorrect judgments. In other cases, one may come to a perfectly logical conclusion using analytic processing and a negative outcome could still occur. Similarly, someone could make a faulty conclusion analytically or intuitively and end up with a positive outcome, perhaps by sheer luck. So we must keep in mind that there is not going to be a "best" way to make decisions that always results in good outcomes; rather that, depending on the situation at hand, one process may be more appropriate, resulting in favorable outcomes more often.

There is empirical evidence that the intuitive and deliberative processes develop with age (Klaczynski, 2005). Piaget's stage of formal operations includes the development of reasoning and problem solving abilities in adolescence (Inhelder & Piaget, 1958) which is demonstrated by abilities to think abstractly and hypothetically. Cognitive capacity, metacognitive reasoning, and executive functioning also increase with age (Klaczynski, 2005; Kuhn, Katz, & Dean, 2004; Morsanyi & Handley, 2008; Steinberg, 2007), leading to heightened ability to be analytical when making decisions. Klaczynski and Cottrell (2004) showed that adolescents were better able than children to reflect on previous decisions when presented with new problems. Similarly, adults were better able to incorporate previous feedback into future decisions (Byrnes et al., 1999).

Furthermore, Galotti (2005) showed that as individuals aged from early elementary school to late high school, adolescents' goals increased in complexity, defined as several parts or subgoals, difficulty, and controllability. Another study showed that when asked to help peers solve a hypothetical dilemma, adults were more likely than adolescents to consider consequences of decisions and to suggest seeking advice (Halpern-Felsher & Cauffman, 2001).

The intuitive system is also developing into and throughout adolescence. This is partly because of personal experience. The more experience one has, the more one relies on the judgment and decision heuristics created by those past experiences and the consequences of previous decisions. As children and adolescents age and as their heuristics are compiled, their general processing becomes more and more automatic and intuitive because they can use heuristics rather than thinking about decision options and consequences quite as thoroughly. Morsanyi and Handley (2008) showed that between 5 and 11 years of age, children were more likely use heuristics in decisions, such as the conjunction fallacy and the sunk cost fallacy. The conjunction fallacy occurs when people think two statements are more likely to be true than one statement. For example, if individuals were asked whether Mary, the political science major, is more likely to be a teacher or more likely to be a teacher and donate money to political candidates, they may be inclined to say that she is more likely to be both a teacher and donate money, however, one statement is always more likely to be true than two statements. The sunk cost fallacy occurs when people continue to participate in an activity they are no longer enjoying because they have already spent money or time on the activity. Furthermore, because the intuitive process expends little cognitive effort, it is likely to be relied on more and more

as the complexity and number of decisions to be made increases (Reyna, Adam, Poirier, LeCroy, & Brainerd, 2005; Klaczynski, 2005).

Theoretically, both systems are eventually fully developed, and by adulthood individuals have a repertoire of decision making strategies, allowing flexibility and variability in the ways they make decisions and solve problems (Byrnes, 2005). Ideally, adolescents should use their analytical abilities to monitor and evaluate the outcomes of their decisions (Klaczynski, 2005), thereby learning when to use each process and becoming better decision makers. However, as suggested by the neurobiological model, described later, adolescents are not likely to be deliberating over decisions involving risk behaviors.

In summary, adolescents are thought to be developing both the deliberative and intuitive systems of decision making with the ideal end result of being able to use the appropriate process depending on the situation. However, these decision making processes have rarely been related to real-world risk behavior. Some researchers of adolescent decision making and risk behavior have attempted to empirically link decision making processes with risk behavior, but the empirical studies generally examine constructs that affect decision making (e.g., weighing risks and rewards), not decision making processes specifically.

Variations on the dual-process models of risk-taking. Variations on the traditional dual-process theories have been developed to attempt to explain adolescent risk behavior. One is called fuzzy trace theory. According to fuzzy trace theory, instead of two distinct processes (analytical and intuitive), there is a continuum ranging from verbatim representation to gist representation (Reyna et al., 2005), which means that any

decision could be slightly more or less based on verbatim or gist representation. Verbatim representation is the precise *quantitative* recollection of an event (which could be the consequence of a previous decision) whereas the gist representation is an imprecise, *qualitative*, categorical form of recollection in which a general sense or impression of the event comes to mind, including its emotional meaning (Reyna, 2004; Kahneman, 2003). The proponents of fuzzy trace theory state that the natural habit of the mind is to think imprecisely and intuitively about decisions (Reyna et al., 2005), which accords with the principle that the intuitive system dominates most decision making. The proponents of this theory argue that gist-based decision making should prevent risk behavior. This is because more mature decision makers do not weigh possible rewards and risks or the likelihood of each, but rather think about the possibility of a catastrophe; and since there is always the possibility of a catastrophe with risk behavior, the mature decision maker will decide not to engage in the behavior (Reyna et al., 2005). Furthermore, using verbatim representation and thinking through all possible consequences and the likelihood of each could lead an adolescent to rationally make the decision to engage in risk behavior because the probability of a catastrophic consequence is often relatively low (Reyna, Estrada, DeMarinis, Myers, Stanisz & Mills, 2011; Reyna et al., 2005). For example, in the case of sex education, if adolescents are taught about quantitative trade-offs between risks and rewards, an adolescent could come to a logical conclusion that the risks are relatively low and the rewards potentially high and could ultimately decide to have unsafe sex (Beyth-Marom & Fischoff, 1997). The extension of this theory to practice is that interventions should be designed to present gist-based

representations of negative consequences of risk behavior that the adolescent will use when making decisions about risk behavior.

There are some drawbacks to this model. First, it is only applicable if parents or educators are able to instill an "anti-risk" gist in adolescents and then assume that the same gist will remain the primary factor of any future decision making and for all decisions regarding risk behaviors. However, adolescents may experiment with drinking, drugs, or sex and find that these activities are rewarding and that nothing catastrophic happened. This would ruin the "anti-risk" gist, perhaps replacing it with a "pro-risk" gist, which would potentially lead to more and varied forms of risk taking. Second, the model does not take peer influences into account. Although fuzzy trace theory includes the influence of emotions, they are not considered in the context of peer influence, which is a significant oversight, considering the importance of peer relationships in adolescence (see Brown, 2004). If parents and educators are ingraining the disastrous images of risk behavior into adolescents, and then a friend or romantic partner has a different idea, there is a possibility that adolescents may align themselves with their peers. Furthermore, research on executive function and intelligence has shown relations to more analytical processing as well as less risk behavior (Jaccard, Dodge, & Guilamo-Ramos, 2005; Hall, Elias & Crossley, 2006), which is contrary to fuzzy trace theory because fuzzy trace theory contends that more analytical processing should be related to more risk. A recent study by Reyna and colleagues (2011) suggests that neurobiological and memory (e.g., fuzzy trace) models could each explain unique variance in risky decision making – an interesting possibility that will be further explored in the discussion.

A second dual-process model that attempts to explain adolescent risk behavior is the prototype willingness model, which hypothesizes two paths, a reasoned path and a social reaction path, which operate simultaneously and may lead to making decisions to engage in risk behavior (Gerrard, Gibbons, Stock, Vande Lunde, & Cleveland, 2005; Gerrard, Gibbons, Houlihan, Stock, & Pomery, 2008). The reasoned path is similar to deliberative processing in that it involves intentional decision making. The social reaction path implies that risk taking occurs as a response to a specific social situation and is not planned. This model introduces important constructs to the decision making and risk behavior research, such as behavioral willingness, which suggests that most risk behavior is not planned, but rather that adolescents who are more open to engaging in risk behavior, are more likely to do so when the opportunity arises. Also, the model incorporates the idea of risk prototypes which suggests that adolescents have clear images of the type of person who engages in risk behavior and the favorability of that prototype is related to engaging in risk behavior. Thus, according to this model, peer influence is an important contributor to decision making about risk behavior because one's peers inform one's risk prototypes. A contribution of this model is that individual differences, particularly in risk prototypes and behavioral willingness, are highlighted. However the prototype willingness model narrowly defines the problem of risk behavior, taking into account only a few aspects of social and cognitive psychology. It also does not address how any of its facets, including the reasoned path, risk willingness, or risk prototypes, develop. In other words, although this model claims to target adolescent risk behavior, it does not take developmental issues specific to adolescence into account.

In summary, risk taking peaks in adolescence and declines thereafter. Cognitive abilities as well as reliance on heuristic thinking are developing into and throughout adolescence and into adulthood (see Boyer, 2006). It seems clear that adolescent risk behavior cannot be described by decision making abilities alone.

Neurobiological model. The neurobiological model developed by Steinberg and colleagues (Steinberg, 2007; Steinberg, 2008; Steinberg et al., 2008; Steinberg, 2010b) is based on emerging brain development research and research on psychosocial factors. The neurobiological model is a different type of dual-process model, but there is overlap between this model and the other dual-process models described so far. The major difference between the neurobiological model and other dual-process models is that the two systems invoked to explain decision making and risk taking are brain systems (Steinberg, 2010a; 2010b; Steinberg, 2007) not specific decision making processes. The neurobiological model posits a cognitive control system, which may parallel the analytic process, and a socio-emotional system, which may parallel the intuitive process. The components of the cognitive control system involve regulatory functions, such as planning, resisting temptation, and self-regulation. The cognitive control system is similar to and augments the analytical system of other dual-process models because it involves the ability to deliberate over decisions, think precisely, and also to inhibit sensation seeking. Basically, it helps control the impulses of the socio-emotional system, which are related to reward and novelty seeking.

In contrast to the cognitive control system, the socio-emotional system is quick to react, acts without awareness, and is sensitive to rewarding social and emotional stimuli (Steinberg, 2007). This is similar to descriptions of the intuitive decision making

process, which operates quickly, outside of awareness, and uses emotional information. The systems of the neurobiological model and the processes of dual-process models therefore appear to be similar. Furthermore, the traditional dual-process theory and the neurobiological model both suggest that development of the two systems or processes is complete when most decisions are made quickly or impulsively, but deliberation and control take over when necessary (Klaczynski, 2005; Steinberg, 2008). Having common indicators of the processes and common endpoints of development suggests that these theories may be complementary. In other words, each theory may benefit from inclusion of the other's constructs and methods.

According to the neurobiological model, adolescents are more likely than children to take risks because the socio-emotional system develops in early adolescence, around age 14 perhaps co-occurring with puberty, when opportunities for risk taking behavior also increase. The cognitive control system continues to develop gradually into the early to mid-20s. This mismatch in the developmental timing of the two systems leads to increased risk-taking during adolescence, especially in the presence of peers (Gardner & Steinberg, 2005; Steinberg, 2008). In other words, adolescents begin to be especially stimulated by rewarding and novel stimuli before their self-regulatory capacities can intervene, and increased risk-taking behavior is the result.

Developmental changes in brain circuitry. The development of the socio-emotional system and cognitive control system are driven by brain maturation. Steinberg proposes that changes in the socio-emotional system are largely due to changes in the brain's dopamine system. Dopamine is the neurochemical basis of reward (Ernst & Spear, 2009), which has been implicated in reward-related learning (Chambers, Taylor, &

Potenza, 2003). Dopamine plays a critical role in the brain's reward circuitry, so the increase, reduction, and redistribution of dopamine receptors that happens in early adolescence may have important implications for sensation seeking (Steinberg, 2008). Dopaminergic activity plays a critical role in affective and motivational processing, which is integral for social and emotional processing (Spear, 2000; Steinberg, 2010b; Steinberg, 2008). The brain structures associated with the dopamine processes include the amygdala, nucleus accumbens, orbitofrontal cortex, medial prefrontal cortex, and superior temporal sulcus (Nelson, Leibenluft, McClure, & Pine, 2005). Some brain regions involved in reward sensitivity overlap with regions involved in social and emotional processing, such as the ventral striatum and the medial prefrontal cortex (see Steinberg, 2008). Also, the density of dopamine transporters which remove dopamine from the synapse peaks during adolescence in the striatum, which implies increased movement of dopamine from neuron to neuron. In one study, adolescents showed higher activation than adults in the orbito-frontal cortex and ventral striatum in anticipation of reward (Geier et al., 2010) suggesting heightened dopamine activity among adolescents. In animal models, dopamine receptor density appears to increase around puberty and decrease in late adolescence in the striatum and prefrontal cortex (Sisk & Foster, 2004). The general remodeling of the system likely leads to an increase in dopamine activity in the straitum during early adolescence, which would perhaps interfere with self-control. Behaviorally, an increase in dopamine activity suggests that pleasure obtained from rewarding stimuli is increased (Steinberg, 2010b), and individuals may be especially likely to seek out rewarding activities.

The brain changes responsible for the development of the cognitive control system include general synaptic pruning, perhaps most significantly in the prefrontal cortex (Keating, 2004), and the continued myelination of prefrontal brain regions. Both of these changes result in improved connectivity among cortical areas, including the dorsolateral prefrontal cortex, anterior and posterior cingulate, and temporo-parietal cortices. The increased connectivity within these areas allows for development of many aspects of executive function, such as response inhibition, planning ahead, weighing risks and rewards, and the simultaneous consideration of multiple sources of information (Steinberg et al., 2008; Steinberg, 2008). In other words, the cortical brain regions responsible for cognitive control are able to be activated and could possibly override the responses of the subcortical regions, which are sensitive to rewarding social and emotional stimuli. The changes in the cognitive control system occur gradually and are not completed until the mid-20s (Steinberg, 2008). In summary, according to this model, most risk behavior declines in adulthood because the maturity of the cognitive control system eventually matches the maturity of the socio-emotional system. Ideally, the cognitive control system is capable of monitoring and/or overriding responses of the socio-emotional system when necessary (i.e., when one is about to do something dangerous).

Empirical evidence of the neurobiological model. Empirical evidence supports the existence of the two systems. One recent analysis of age differences in performance on the Iowa Gambling Task (a typical laboratory decision making task that involves risks and rewards) found that reward sensitivity increases between ages 10 and 16 and then declines thereafter (congruent to conceptions of the development of a socio-emotional

system). Thus, reward sensitivity in included in the present conceptualization of the socio-emotional system. Attentiveness to punishment, however, increases gradually and linearly with age (congruent with the timing of development of the cognitive control system; Cauffman et al., 2010) and is included in the conceptualization of cognitive control. These findings lend support to the argument that heightened risk taking in adolescence, relative to childhood or adulthood, may be due in part to an increase in reward salience during adolescence. Another study showed that younger adolescents were more likely than young adults to engage in delay discounting, which means that they were more likely to prefer a smaller reward that they would receive sooner as opposed to a larger reward that they would have to wait for (Steinberg, Graham, O'Brien, Woolard, Cauffman, & Banich, 2009). Regarding the cognitive control system, future orientation variables such as planning ahead and anticipation of consequences of decisions was relatively low among younger adolescents, but continued to develop into early adulthood (Steinberg et al., 2009). Therefore, future orientation is included in the cognitive control system. Similarly, performance on the Tower of London (a behavioral task designed to assess goal-directed planning which involves arranging items in a specified way in the fewest number of moves) improved through the early twenties and was fully mediated by impulse control (Albert & Steinberg, 2011). This suggests that planning and controlling one's impulses are directly related to each other. In yet another study, sensation seeking was found to peak in early adolescence and then decrease, following a curvilinear pattern, which is the same timeline as development of the socio-emotional system and included in the present conceptualization of the socio-emotional system, whereas impulsivity was found to decrease linearly into young adulthood

(Steinberg et al., 2008), potentially suggesting a linear increase in self-regulation, which is the same timeline as development of the cognitive control system and included in the conceptualization for the cognitive control system.

Studies on peer influence, a likely source of rewarding stimuli, provide further evidence of the mismatch between the two systems during adolescence. A study of the effect of peer influence on adolescents' risky decisions in the context of a simulated driving task demonstrated linear development of resistance to peer influence. Some participants had a peer present and some did not. Results showed that peer presence strongly affected adolescents' "risky" driving decisions before age 18, then the peer effect decreased, and by age 24 peers had a negligible effect (Gardner & Steinberg, 2005). Similarly, a paper and pencil measure of resistance to peer influence (part of the cognitive control system) showed that individuals increased in their resistance between ages 14 and 18, but there was no age-related change for younger or older adolescents (Steinberg & Monahan, 2007; Sumter, Bokhorst, Steinberg, & Westenberg, 2009). In a different social exposure experiment, young adult participants aged 19-30 who observed peers participate in a gambling task and saw the outcomes of the peers' choices were more likely to make a risky selection on the same task (Yechiam, Druyan, & Ert, 2008). These studies suggest that socio-emotional system constructs, including reward sensitivity, susceptibility to peer influence and delay discounting, develop early in adolescence and are a strong factor in making decisions throughout adolescence. Furthermore, the cognitive control system involves constructs that could be loosely categorized as cognitive, emotional, behavioral, and social regulatory capacities and continues to develop into early adulthood.

The neurobiological model is the basis for the present study for a number of reasons. First, this model describes the unique aspects of adolescence that help to explain the emergence of risk-taking behaviors. Second, it explains why risk-taking eventually declines in adulthood. Finally, it provides a more coherent and exhaustive explanation of adolescent development because it includes or at least acknowledges many aspects of development, including biological, social, temperamental, emotional, and cognitive changes, all of which may help to explain why adolescents are at an increased risk for endangering themselves by making unhealthy and potentially dangerous decisions. The research questions were designed to strengthen the empirical evidence related to the neurobiological model, merge it with more traditional conceptions of the dual-process model, and address current shortcomings of the model.

It has been suggested that the neurobiological model may be a new "grand theory" of adolescent development in the vein of Erikson or Piaget (Steinberg & Lerner, 2004; Steinberg, 2010a). While this remains to be seen, it does incite many new questions and research possibilities, a few of which are addressed in this study. First, as previously mentioned, this neurobiological dual-systems model has some similarities with other, more traditional dual-process decision making models, but the potential associations between deliberative/intuitive processing and the cognitive control/socio-emotional systems have not been tested. The current study examined some of these connections. Second, risk behaviors have been typically operationalized as gambling behaviors in a laboratory setting (Cauffman et al., 2010; Steinberg et al., 2009) or as antisocial activities of antisocial youth (Monahan, Steinberg, Cauffman, & Mulvey, 2009). It is presumed that these types of risk will translate to other types of risk behavior,

such as substance use, risky sexual behavior, and more moderate forms of delinquent behavior, but no studies have tested this. The current study tested associations between deliberative and intuitive decision making and "real-world" risk behaviors, which to my knowledge has only been tested in adults or with a behavioral decision making task. Finally, the neurobiological model is mainly a developmental model and has not yet accounted for many individual and social differences that may moderate the relation between the socio-emotional system and risk behavior and help account for adolescents who avoid risk behavior. The next section introduces some potential individual and social differences that are likely to influence the processes associated with the neurobiological model and risk behavior.

Individual and Social influences on Adolescent Decision Making and Risk Behavior

Epstein and Pacini (1999) reported that everyone employs both the deliberative and intuitive styles of decision making, but there are important individual differences in the quantity and quality of their use. For instance, temperamental aspects, such as self-regulation, are thought to be important for adolescents to make good decisions (Byrnes, 2002; Steinberg, 2007). Although the neurobiological model characterizes self-regulation as a developmental variable generally defined as controlling impulses, there are also individual differences in levels of self-regulation among adolescents of the same age (Raffaelli & Crockett, 2003).

Surprisingly little research has been devoted to individual risk taking in a social context (Yechiam et al., 2008). Peers are clearly an important social influence which engages the socio-emotional system by increasing the rewarding aspects of various behaviors, likely affecting decisions. Although some young people are more susceptible

to peer influence than others (Allen, Chango, Szwedo, Schad, & Marston, 2012), it is reasonable that if friends tend to engage in risk behavior or are even present, adolescents may be at increased risk of engaging the socio-emotional process, highlighting the rewards of risk taking more so than for individuals with friends who typically do not engage in risk behavior. Therefore, deviant peers may exacerbate the relationship between socio-emotional processes and risk behavior. Possibly, the positive effect of deviant peers could also interfere with the cognitive control system, lessening the effect of cognitive control on risk behavior.

Although it should be noted that there are other individual and social variables that would potentially affect decision making and risk behavior, for the purposes of the present study, one variable representing each of the two types of individual differences (temperamental and social) were examined. These variables were chosen because they may play an especially important role in adolescent risk behavior and could moderate the processes of the neurobiological model. The current research extends the conceptualization of the neurobiological model by introducing key social and individual differences, adding breadth to our understanding of this model.

Temperament: Self-regulation. There are several conceptualizations of self-regulation. For this manuscript, self-regulation is defined as the ability to control, monitor, inhibit, persevere, guide and change one's behavior, attention, emotion, and cognitions in line with one's goals and/or social awareness (Brown, 1998; Kopp, 1982; Moilanen, 2007; Neal & Carey, 2005; Raffaelli & Crockett, 2003; Thompson, 1994). According to Byrnes (2002), the need for self-regulated decision making is especially important for adolescents because they are becoming more autonomous and making

decisions on their own without the aid of adults. It is important for adolescents and young adults to be able to make important decisions carefully and thoughtfully and to be somewhat regulated in order to accomplish difficult or complex goals, such as getting a job.

According to the neurobiological model, self-regulation is a key component of the cognitive control system, and continued maturation of this system is thought to be the reason that risk behavior decreases in adulthood. However, self-regulation begins to develop well before adolescence, as early as late infancy (Kopp, 1982), and increases between early and middle childhood (Raffaelli, Crockett, & Shen, 2005). Lower self-regulation has been related to substance use and sexual risk taking in cross-sectional and longitudinal studies of adolescents (Wulfert, Block, Santa Ana, Rodriguez, & Colsman, 2002; Raffaelli &Crockett, 2003; Crockett, Raffaelli, & Shen, 2006). Also, poor cognitive self-regulation, or executive function, was linked to an over-emphasis on the benefits associated with risky activities and a higher incidence of problems associated with excessive alcohol consumption. Furthermore, poor emotion regulation predicted greater participation in risk behaviors such as cigarette smoking and alcohol-induced behaviors such as fighting and arguing (Magar, Phillips, & Hosie, 2008). A study of young adults showed that participants who were successful in regulating their emotions using an imagery-focused relaxation strategy showed a subsequent decrease in risky decision making in a gambling task (Martin & Delgado, 2011). This change in behavior was accompanied by decreased activation in the striatum, providing further evidence of brain areas in the cognitive control system being related to self-regulation. The linkages between self-regulation and risk behaviors indicate that individual differences in levels of

self-regulation should be included in conceptualizations of the neurobiological model, protecting individuals from risk behaviors.

Social influences: Deviant friends. Adolescence is a life stage in which there are changes in the type and importance of social influences on behavior. While family influences remain strong, peers increase in their influence (Brown, 2004). It is an important developmental task to form strong bonds with peers to avoid negative outcomes such as depression (see Allen et al., 2012). There are several ways that peers can affect adolescent decision making. For example, peers can affect decision making directly by giving advice on decisions or indirectly by promoting various goals or modeling different decision making styles. Adolescents tend to seek their friends' advice for shorter term, less important, less difficult and/or more social decisions (Wilks, 1986; Bednar & Fisher, 2003). As peers are at the same life stage, they also provide the opportunity to discuss choices about the goals for the future with others going through similar experiences at the same time (Nurmi, 1991).

Peers are usually conceived as a negative influence on adolescent decision making. Gardner and Steinberg's (2005) study with the simulated driving task experimentally measured immediate risk decisions of adolescents by having them play a video game in which the purpose was to drive somewhere as quickly as possible without crashing, which means deciding whether to run through yellow lights. Some participants completed the task in the presence of a same-age peer that they knew. The adolescent participants were more likely to take risks when in the presence of the peer whereas young adults (age 24 and older) were not, suggesting that adolescents are more susceptible than adults to peer influence (Gardner & Steinberg, 2005). This study implies

that the mere presence of a peer impacts adolescents' (but not adults') decision making. This is consistent with the neurobiological model because peer approval and presence are thought to be rewarding and therefore likely to increase the rewarding sensation of risky behaviors in early to mid adolescence when the socio-emotional system is at its peak. Furthermore, resistance to peer influence appears to increase with age, consistent with the development of the cognitive control system.

Peers also have an effect on decision making because they affect what their friends consider to be normative for their age group. *Beliefs about* what peers are doing can be an influential factor on decisions and the resulting behavior even if those beliefs are incorrect. For instance, people of all ages partake in the false consensus effect, meaning that they assume others' attitudes and behaviors will resemble their own (Loewenstein & Furstenberg, 1991). This allows persistence in attitudes and behavior because people believe that their peers generally agree with them. Pluralistic ignorance refers to the tendency for people to overestimate the population base rates for activities in which they themselves are engaged (Jacobs & Johnston, 2005). This is generally more common with adolescents because it is harder for them to make accurate base-rate estimates of behavior and attitudes due to their limited experience and feedback from earlier decisions (Jacobs & Johnston, 2005). For example, in one study, 7th and 8th grade students responded to questions about their risk behaviors as well as some neutral behaviors like riding a bike or feeling sick (Jacobs & Johnston, 2005). In general, the adolescents overestimated the occurrences of all behaviors among peers. However, adolescents who highly overestimated the occurrences of deviant behaviors were more likely to have engaged in deviant behaviors themselves (Jacobs & Johnston, 2005). This

likely occurs because adolescents must draw on their own experiences and interactions with peers to estimate base-rates of behaviors. Similarly, adolescents who had experienced sexual intercourse believed that significantly more peers also had intercourse as compared those who had not experienced sexual intercourse (Loewenstein & Furstenberg, 1991). The accuracy of base-rate estimates may be related to a variety of individual factors, such as prior experience, motivation, or metacognitive skills (Klaczynski, 2005). Although these studies emphasize what an individual believes his or her friends are doing, it is likely that the actual behaviors of friends will also influence individuals' perceptions of what is normative and individuals will be more likely to engage in the behaviors themselves if they think they are normative.

Having deviant friends is a consistently strong predictor of delinquent activity (Hawkins, Catalano, & Miller, 1992; Dishion, Andrews, & Crosby, 1995; Brendgen, Vitaro, & Bukowski, 2000a; Brendgen, Vitaro, & Bukowski, 2000b; Haynie & Osgood, 2005). There are a number of reasons that deviant friends may affect adolescent risk behavior. For instance, deviant friends reinforce preexisting delinquent or sensation-seeking tendencies (Patterson, Dishion, & Yoerger, 2000). Reinforcement may occur due to deviancy training, which occurs when there is positive discussion of antisocial behavior among peers. Deviancy training predicted delinquent behavior two years later, controlling for prior levels of delinquency (Dishion, Spracklen, Andrews, & Patterson, 1996). This suggests that deviant friends are directly influencing the target individuals' risk behavior and it is not necessarily a matter of choosing friends who are deviant. One recent study found that peer substance use at baseline predicted change in adolescents' substance use, although this effect was exacerbated by other social and contextual

variables (Allen et al., 2012). Consistent with the neurobiological model's assertion that resistance to peer influence is linked to the cognitive control system, which increases into adulthood, it was found that the relations between having deviant friends and antisocial behavior decreased with age in a group of antisocial adolescents (Monahan et al., 2009). According to the neurobiological model, the presence of peers increases the reward sensation of risk behaviors. So, if friends are engaging in risk behaviors and pleasing one's friends is related to reward, then it follows that one would also engage in the risk behavior. Therefore, deviant peers would likely have an increased impact on adolescents' risk behaviors.

In conclusion, individual differences in self-regulation and deviant friends need to be considered in conceptualizations of the neurobiological model, which to date has largely focused on developmental changes. These individual/social variables are likely to matter for decision making and risk behavior in conjunction with age.

The Present Study

The current study is based on the neurobiological model and designed to address gaps in this model. First, as mentioned earlier, this dual-systems model refers to two brain systems, not necessarily two decision making processes like the other dual-process models described in this paper. It is possible (and seems likely) that the indicators of the socio-emotional system including increased sensation seeking, reward sensitivity, and emotional reactivity are related to intuitive decision making because they appear to be indicative of quick processing that occurs subconsciously. Similarly, it is possible that the cognitive control processes including resistance to peer influence, future orientation, and punishment sensitivity are related to deliberative decision making because they are

indicative of thoughtful processing that occurs with conscious effort. These potential relations are investigated in the present study. Second, the variables related to the socio-emotional system are said to be related to risk behavior; however, this has generally been tested with gambling tasks. It is, as of yet, unclear if intuitive decision making is related to "real world" risk behaviors such as substance use, delinquent activity, or risky sexual activity. It is also currently unclear whether deliberative processing is related to abstaining from "real-world" risk behaviors. The current research addresses these gaps by directly examining the relation between deliberative and intuitive decision making and risk behavior. Finally, it is unknown how individual and contextual differences in self-regulation and deviant friends, moderate the relations between the socio-emotional and cognitive control systems and risk behavior. This study examines the potential moderating effects of these variables.

Research Question 1. The neurobiological model is a dual-systems model in that it specifies two brain systems that develop on different timetables, leading to an increase and subsequent decrease in risk behavior. However, it has not been clearly linked to more "traditional" dual-process decision making models, although there are potential overlaps. For instance, sensation seeking of the socio-emotional system implies quick, emotion based processing, similar to intuitive decision making. Self-regulation and similar variables associated with the cognitive control system imply deliberative style processing, in which one thinks through decisions and controls impulses.

Hypothesis 1. Socio-emotional processes (sensation seeking, reward sensitivity, and emotional reactivity) are correlated with intuitive decision making (see Figure 1).

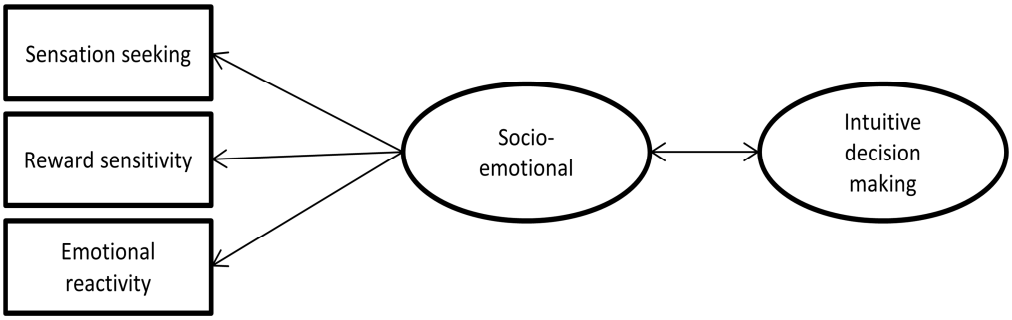


Figure 1. It was hypothesized that there would be a positive relation between the socio-emotional system and intuitive decision making

Hypothesis 2. Cognitive control processes (self-regulation, resistance to peer influence, future orientation, and punishment sensitivity) are correlated with deliberative decision making (see Figure 2).

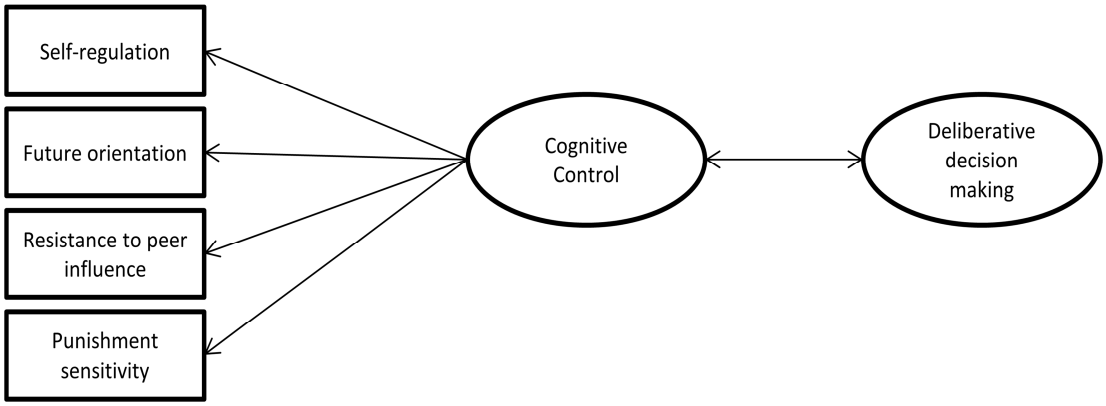


Figure 2. It was hypothesized that there would be a positive relation between the cognitive control system and deliberative decision making

Hypothesis 3. In line with previous research (see Klaczynski, 2005), it is expected that deliberative and intuitive decision making are each positively correlated with age because cognitive abilities and heuristics increase with age.

Research Question 2. The neurobiological model says that the development of the socio-emotional system (in the absence of cognitive control) is to blame for increased risk behavior in adolescence, and development of the cognitive control system is related

to decreased risk behavior. Assuming that the variables of the socio-emotional system are related to intuitive processing and the variables of the cognitive control system are related to deliberative processing, is deliberative decision making or intuitive decision making more likely to predict risk behaviors?

Hypothesis 4a. Deliberative decision making is negatively associated with risk behavior because careful reflection on possible courses of action is suspected to be similar to cognitive control processes and which are expected to lead to healthier decisions.

Hypothesis 4b. Intuitive decision making is positively associated with risk behavior (see Figure 3). Although fuzzy trace theory suggests otherwise, a positive correlation between intuitive decision making and risk behavior was expected because intuitive decision making implies a lack of planning and adolescents often report that most risk behavior is unplanned (Gerrard et al., 2008); therefore, risk behavior should be related to intuitive processing.

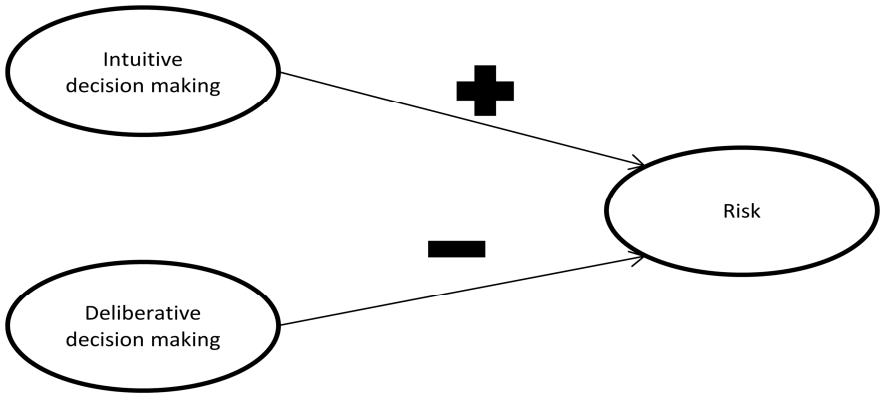


Figure 3. Hypothesized relationship between decision making processes and risk behavior.

Research Question 3. The neurobiological model does not take individual differences in factors influencing adolescent decision making and risk behavior into account. Not all adolescents of the same age participate in the same amount of risk behavior, suggesting that individual differences play an important role in risk behavior. In particular, there may be temperamental and social differences involved in the increase and subsequent decrease of risk behavior. With the intention of being realistic, the present research examined one variable from each domain of interest (temperamental and social) as shown in Figures 4a-4c.

Hypothesis 5: Temperament (self-regulation). Self-regulation develops throughout childhood and adolescence, and differences in self-regulation predict risk behaviors. It was hypothesized that self-regulation would moderate the relationship between socio-emotional processes and risk behavior because those who are more regulated would not be as susceptible to rewarding stimuli (Figure 4a). Specifically, it was expected that the structural path between the socio-emotional latent variable and risk behavior will be significantly weaker for those with higher self-regulation.

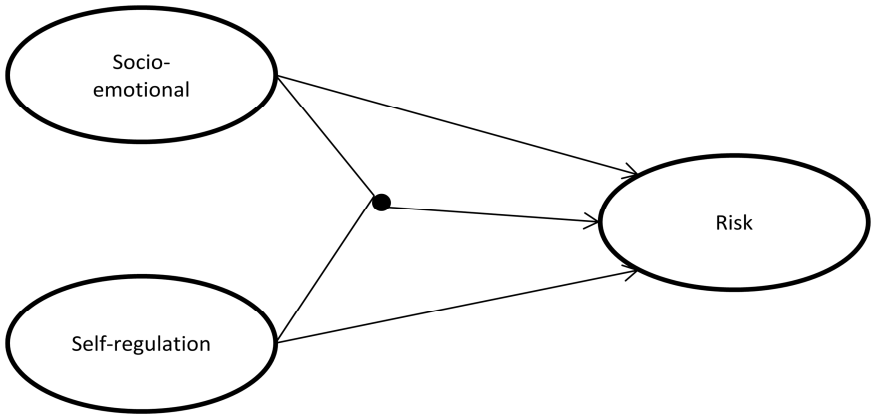


Figure 4a. Hypothesized interaction between socio-emotional process and self-regulation predicting risk behavior.

Hypothesis 6: Social influences (peers). It was expected that affiliating with deviant friends would moderate the relationship between socio-emotional processes and risk behavior, such that the relationship would be significantly stronger for those with deviant friends than those without deviant friends. Deviant friends are a strong and consistent predictor of risk behavior. Most risk-taking occurs in groups, presumably because friends are a source of rewarding stimuli. Therefore having deviant friends not only predicts risk behavior but would also exacerbate the relationship between socio-emotional processing and risk behavior (Figure 4b). Furthermore, deviant peers will moderate the relationship between cognitive control processes and risk behavior such that the relationship will be weaker for those with deviant peers (Figure 4c). Deviant friends may interfere with the regulatory capacities of the cognitive control system by exerting an influence over risk behavior that buffers the cognitive control system.

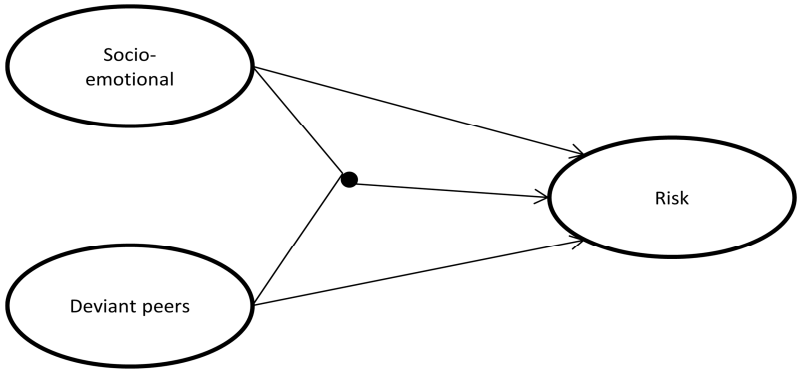


Figure 4b. Hypothesized interaction between socio-emotional process and deviant peers predicting risk behavior.

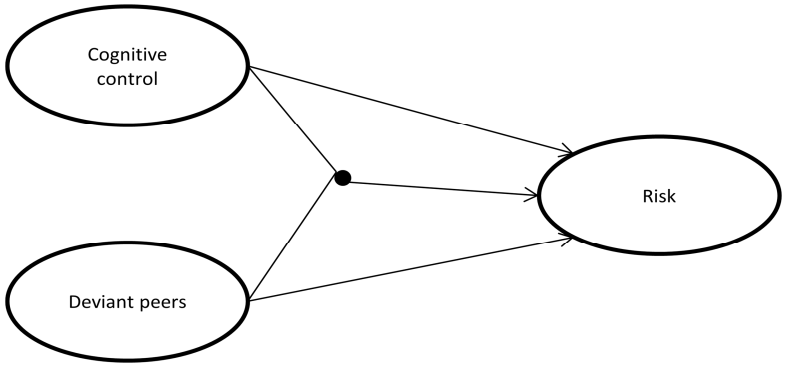


Figure 4c. Hypothesized interaction between cognitive control process and deviant peers predicting risk behavior.

CHAPTER 2: METHOD

Sample

Data were collected from a large public University in the Midwest. A total of 397 undergraduate students completed a questionnaire for course credit. Fifteen participants were not included in the final analyses because they were at least 25 years old and therefore beyond the targeted age range. There were 382 participants in the final sample (62.6% women). The average age was 19.25 (*SD* = 1.33) years old and the racial/ethnic makeup was 84% White, 2.6% Black/African American, 5.0% Latino/a, 6.0% Asian, and 1.8% biracial. Approximately half of the participants had at least one parent with a college degree and just over 70% came from households with an annual income of at least $60,000. For current living situation, 52% lived in a dorm, 3.7% lived in an on-campus apartment, 12.8% lived in a Greek House, 20.7% lived off-campus with roommates, 3.1% lived off-campus alone, 6.5% lived with parents or guardians, and 0.8% lived with a significant other and/or children. The rates of risk behavior participation were similar to other samples in terms of alcohol use, but this current sample may have had more individuals who were smokers and used marijuana (see Johnston et al., 2011).

Measures

All measures were based on self-report.

Demographics. Age, ethnicity, and gender (0 = men, 1 = women) were included in the questionnaires. Due to relatively low frequencies of many of the racial and ethnic categories, race was re-coded combining the three lowest frequency categories. The resulting race variable (White, Asian, and combined Black, Latino, and Biracial) was dummy-coded with Whites as the reference group. Parent's degree of education, income,

and occupation were included to serve as proxies for socio-economic status. Education was originally on a scale from 1 (*less than 7th grade*) to 9 (*doctoral degree*). Few participants had parents with less than a high school degree, so responses were re-coded with 1 referring to any education less than high school. For those who gave education levels for two parents or guardians, education level was averaged across parents. If respondents indicated one parent's education level, then the score for that parent was retained. Annual family income was ranked on scale with responses from 1(*0 - $15,000*) to 8 (*over $105,000*). Occupational status was assessed following the recommendation of (Davis, Smith, Hakao, & Treas, 1991). Participants were shown a list of example jobs and told to choose which was most similar to what their parents or guardians did for living. For example, the occupations of day laborer, food preparation worker, or janitor were labeled as 1; occupations of physician, aerospace engineer, or CEO were labeled as 8. Relatively more prestigious occupations were ranked higher. For those who responded that two parents or guardians had jobs, occupation was averaged across parents. If respondents indicated that only one parent had a job, then the score for that parent was retained. Participants' living situation was also included because individuals may have increased opportunities for risk behavior if they live on their own or with roommates compared to living with parents or in college dorms. Response options were on-campus dorm, on-campus apartment, Greek house, off-campus with roommates, off-campus by yourself, with legal guardians, and other. All participants who chose "other" lived with a significant other and/or children, so a new category was created. Due to low frequencies of some categories, residence was re-coded for inclusion as controls in the main analyses. The new categories were on-campus, Greek House, off-campus with

roommates or alone, and off-campus with parents or other family. These categories were dummy coded with on-campus as the reference group.

Psychometric Evaluation. Latent variables reflecting study measures were identified by fitting a single latent factor with items as indicators. Assessment of good model fit was provided by the Comparative Fit Index (CFI), with values greater than .95, the Root Mean Square Error of Approximation (RMSEA), with values less than .06, and the Standardized Root Mean Squared Residual (SRMR) with values less than .08 (Hu & Bentler,1999). Mplus 5.1 (Muthén & Muthén, 1998-2010) was used for all CFAs and primary study analyses. Modification indices were examined for potential correlated errors that improved model fit. Parameter estimates were examined before and after adding correlated errors to ensure that they did not change the model drastically. Maximum likelihood with robust standard errors (MLR) was used. After CFAs were conducted on each measure, latent variables of socio-emotional processing (indicated by reward sensitivity, emotional reactivity, and sensation seeking) and cognitive control (indicated by self-regulation, resistance to peer influence, future orientation, and punishment sensitivity) were estimated.

Adolescent risk behavior. Risk behavior was examined as an overall latent variable and types of risk behavior were examined separately. This was because, although there are similarities in the predictors of risk behavior, (Savin-Williams & Diamond, 2004; Chassin et al., 2004), there may also be important differences between types of risk behavior. For instance, risk behaviors may have different short-term and long-term consequences and some may be relatively more "normative," which may affect the decision making process. For example, substance use can lead to physical illness in

the short term and possible addiction in the long term. Drinking alcohol also tends to be more normative, especially in a college sample, whereas more serious risk behavior may be more strongly predicted by factors that are less common (e.g., deviant friends). Sexual risk-taking is unique in terms of risk behaviors because healthy sexual development is important for future sexual/romantic relationships, but there are, of course, potential negative consequences of risky sexual activity including unintended pregnancy, sexually transmitted diseases, decline in school attendance and educational aspirations, and relations with other types of risk behavior (Savin-Williams & Diamond, 2004).

Therefore, a variety of adolescent risk behaviors were assessed including various types of substance use, risky sexual behavior, and delinquency (Johnston, O'Malley, Bachman, & Schulenberg, 2009; CDC, 2010; Crockett et al., 2006). For substance use, questions were asked regarding tobacco use (e.g., "How often have you smoked cigarettes?" and "How often have you used smokeless tobacco?") with response options ranging from 0 (*never*) to 9 (*every day or almost every day*). The same basic questions with the same response options were used for alcohol use and other recreational drug use. For alcohol use, questions were asked about the frequency of drinking alcohol, getting drunk, binge drinking, and driving while intoxicated. Drunk driving was positively skewed and had high kurtosis so it was square root transformed. The other three items, which were on the same response scale were averaged so that a single alcohol use variable could be used as an indicator of a latent general risk variable. Just under 13% of the sample indicated using drugs other than marijuana, so a single dichotomous variable was created indicating whether participants had ever used any illegal drugs other than marijuana. The marijuana use item was square root transformed because it was positively

skewed. Drug use and marijuana use were each used only as single item indicators in addition to being included in a latent variable of overall risk behavior.

Risky sexual behavior included questions about whether participants ever had sex, number of total lifetime sexual partners (with response options ranging from 1[*1*] to 5[*more than 4*]), condom use and other birth control use (e.g., "How often do you (or does your partner) use a condom when you have sex?") with response options ranging from 1 (*always*) to 5 (*never*) so that higher scores indicated riskier behavior. Condom use was negatively correlated with other types of birth control; perhaps because most individuals believe that one type of birth control is effective enough and if they already use one form of contraception, they are less likely to use another. Therefore, only number of partners and condom use were used as single item indicators of risky sexual behavior and included in the general latent risk behavior variable.

For delinquent behaviors, questions were asked about stealing, fighting, vandalism, and arrest, e.g., "How often did you deliberately damage property that didn't belong to you?" with response options ranging from 0 (*never or not in past year*) to 7 (*about once a week*). An item about threatening someone with a weapon was dropped because too few participants engaged in this behavior. An item about being arrested was also dropped because no participant had ever been arrested more than once and very few had been arrested even once, reducing variability. The final scale had nine items (α = .67) and a CFA revealed good model fit, $\chi^2(25) = 28.42$, $p < .001$, CFI = .99, RMSEA = .02, SRMR = .05, once two correlated errors were added. An average delinquency score was also created to use in the general risk behavior latent variable and square rooted because it was positively skewed and had kurtosis.

For the general risk latent variable, because drug use was modeled as a dichotomous variable, fit statistics were not available. Without drug use in the model, model fit was good ($\chi^2(14) = 40.38$, $p < .001$, CFI = .96, RMSEA = .07, SRMR = .04) so it was assumed the latent variable was appropriate when drug use was in the model. For the Research Questions about risk behavior the following dependent variables were used: (1) latent general risk behavior indicated by alcohol use, number of sexual partners, condom use, drug use, marijuana use, tobacco use, and drunk driving; (2) latent alcohol use indicated by frequency of drinking, frequency of binge drinking, frequency of intoxication, and square-rooted drunk driving, which fit as a single latent factor ($\chi^2(2) = 2.94$, $p < .37$, CFI = 1.00, RMSEA = .04, SRMR = .01); (3) latent substance use indicated by drug, marijuana, tobacco, alcohol use (the average of frequency of drinking, binge drinking, and drinking to intoxication), and square-rooted drunk driving (fit statistics without drug use: $\chi^2(14) = 32.44$, $p < .001$, CFI = .99, RMSEA = .06, SRMR = .04); (4) observed number of sexual partners (single item); (5) observed condom use (single item); (6) observed smoking (single item); (7) observed marijuana use (single item); (8) observed drug use (single item – dichotomous); (9) latent delinquency, whose model fit is described above in the Measures section. For a path diagram of the general risk behavior variable, see Figures 7 and 8. For the sexual risk taking items, only participants who responded that they had engaged in sexual intercourse (72.8%) were included in the analyses.

Deliberative and intuitive decision making. Two measures were used to assess the two decision making processes: the Preference for Intuition and Deliberation Scale (PID) (Betsch, 2004 as cited in Richetin, Perugini, Adjali, & Hurling, 2007) and the

Rational-Experiential Inventory (REI) (Pacini & Epstein, 1999), which have 18 items and 38 items, respectively. The response options ranged from 1 (*strongly disagree*) to 5 (*strongly agree*). The PID showed good test-retest reliability in previous studies (Richetin et al., 2007). The REI had good internal consistency and concurrent validity in a previous study (Pacini & Epstein, 1999). In the current study, internal consistency was low for the PID ($\alpha = .51$) and CFAs on the scales separately and combined revealed bad model fit. In order to examine decision making more directly (as opposed to related constructs, such as a preference/dislike for abstract thinking), only items that were specifically regarding making decisions were analyzed in a CFA, which revealed good model fit: for deliberative decision making, $\chi^2(27) = 45.28$, $p = .02$, CFI = .97, RMSEA = .04, SRMR = .04) and for intuitive decision making, $\chi^2(31) = 61.13$, $p < .001$, CFI = .95, RMSEA = .05, SRMR = .04). Two correlated errors were added to the deliberative decision making and four were added to the intuitive decision making model. These new scales were used as latent variables in the primary analyses. See Appendix A for all items. An example item in the final deliberation scale (9 items, $\alpha = .79$) is "Before making decisions, I first think them through." An example item in the final intuition scale (10 items, $\alpha = .76$) is "With most decisions it makes sense to completely rely on your feelings."

Sensation seeking. A subset of items from Zuckerman's Sensation Seeking Scale (SSS; Zuckerman, 1979) was used to assess novelty and reward seeking, following Steinberg et al. (2008). This scale originally had binary response options (*yes/no*); however, using multiple ordered-response categories can be more informative and reliable (Embretson & Reise, 2000), so the scale was adjusted so that response options were on a Likert scale ranging from 1(*strongly disagree*) to 5 (*strongly agree*). An

example item is, “I like doing things just for the thrill of it.” In the SSS, the six items used were chosen to avoid using items that may reflect impulsivity, as sensation seeking and impulsivity are distinct constructs (Steinberg et al., 2008). The scale was found to have good model fit with two correlated errors ($\chi^2(7) = 23.34$, $p < .001$, CFI = .98, RMSEA = .08, SRMR = .03), although the RMSEA was slightly high, and good internal consistency ($\alpha = .83$).

Reward sensitivity. The reward sensitivity subscale (10 items) of the Sensitivity to Reward and Sensitivity to Punishment Questionnaire (short form) (SRSPQ-S; Torrubia, Ávila, Moltó, & Caseras, 2001) was used to assess attraction to rewarding stimuli. The short form improved on some psychometric issues and correlated highly with the original scale (r = over .90 for each subscale) (Cooper & Gomez, 2008). A sample item of the reward sensitivity subscale is, “Do you like being the center of attention at a party or social meeting?” with response options ranging from 1(*never*) to 5(*always*). Items that were negatively inter-correlated were dropped from the scale. The final reward sensitivity ($\alpha = .68$) scale with one correlated error showed good model fit, except that the CFI was a little low ($\chi^2(7) = 72.73$, $p < .001$, CFI = .91, RMSEA = .06, SRMR = .05).

Emotional reactivity. Two scales were used to assess emotional reactivity: The Affect Intensity measure (AIM; Larsen & Diener, 1987) and the Mood Survey (Underwood & Froming, 1980). Items were chosen that, based on face validity, pertain specifically to emotional lability and emotional intensity because these constructs are likely to pertain to the socio-emotional system. The AIM was originally composed of 40 items, e.g., “When I am excited over something I want to share my feelings with

everyone," with response options ranging from 1 (*never*) to 6(*always*). The Mood Survey originally included 16 items, e.g., "I may change from happy to sad and back again several times in a week," with response options ranging from 1 (*strongly agree*) to 6 (*strongly disagree*). Items were coded so that higher scores were indicative of more emotional reactivity. Items that were negatively inter-correlated or did not load onto a single factor were dropped. A CFA of the final single factor ($\alpha = .72$) indicated good fit once four correlated errors were added, $\chi^2(23) = 70.16$, $p < .001$, CFI = .94, RMSEA = .07, SRMR = .05. The latent variable was used in the primary analyses.

Resistance to peer influence. Participants read 10 pairs of statements and chose which statement best described them. Then respondents indicated whether the statement was "really true" or "sort of" true of them. The responses were coded on a 4-point scale ranging from "really true" of one descriptor to "really true" of the other descriptor. Higher scores indicated a higher resistance to peer influence. A sample item is, "Some people go along with their friends just to keep their friends happy BUT other people refuse to go along with what their friends want to do, even though they know that it will make their friends unhappy," (Steinberg & Monahan, 2007). A CFA revealed good fit with two correlated errors added ($\chi^2(34) = 64.02$, $p < .001$, CFI = .95, RMSEA = .05, SRMR = .04 and had adequate internal consistency ($\alpha = .75$). The latent variable was used in the primary analyses.

Self-regulation. Participants completed the Self-Regulation Questionnaire-Short form (SSRQ) (Carey, Neal, & Collins, 2004). It included 19 items ($\alpha = .85$), e.g., "I am able to accomplish goals I set for myself," with response options ranging from 1 (*strongly disagree*) to 5 (s*trongly agree*). Items were dropped if were specifically about decision

making so that the measures would not be confounded. CFA results with four correlated errors revealed acceptable model fit, $\chi^2(100) = 200.17$, $p < .001$, CFI = .92, RMSEA = .05, SRMR = .05. The latent variable was used in the primary analyses.

Future orientation. This measure included 11 items ($\alpha = .85$) that assess time perspective, future consideration, planning and goals, e.g., "I can see my life 10 years from now," with response options ranging from 1 (*never*) to 4 (*always*). Some items were taken from a measure was created by the NICHD Early Child Care Research Network from various scales measuring similar constructs. Other items assessing came from a scale of educational and occupational expectations (Seginer, 2009). A CFA showed good fit with correlated errors added, $\chi^2(31) = 73.03$, $p < .001$, CFI = .95, RMSEA = .06, SRMR = .04.

Punishment sensitivity. The punishment sensitivity subscale (14 items) of the SRSPQ-S (described above; Cooper & Gomez, 2008) was used. Again, the response options from the original scale are dichotomous (*yes/no*), however, ordered category-response options were used instead ranging from 1(*never*) to 5(*always*). This scale had good model fit after correlated errors were added ($\chi^2(86) = 198.85$, $p < .001$, CFI = .93, RMSEA = .06, SRMR = .05) and good reliability ($\alpha = .86$) A sample item is, "Are you often afraid of new or unexpected situations?"

Deviant friends. Participants completed the Deviant Peer Group Affiliation questionnaire (18 items) (Dishion, Patterson, Stoolmiller, & Skinner, 1991). The original scale included both negative (e.g., How many of your friends got drunk?) and positive (e.g., How many of your friends do or have done volunteer work?) peer activities with response options ranging from 1 (*none*) to 5 (*almost all*). Only the items reflecting

negative behaviors were used to address the research hypothesis about the influence of deviant peers. This measure had good internal consistency ($\alpha = .86$). Three items were dropped due to low variability. CFA results of the final measure showed acceptable model fit, $\chi^2(31) = 113.15$, $p < .001$, CFI = .94, RMSEA = .08, SRMR = .05).

Procedure

In groups of 5-15, participants were seated in an empty classroom. Consent forms were handed out and explained by a research assistant. After consent was obtained, participants were handed the questionnaire and read instructions for completing it. After finishing, participants turned in the questionnaire to the research assistant and were instructed on providing a DNA sample with a cheek swab (see Appendix C for further description).

Data Analytic Plan

Structural equation modeling (SEM) was the approach used for the primary analyses. SEM models relationships among latent variables and estimates random measurement error (Cheung & Lau, 2007; Kline, 2005). Latent variables involve several observed indicator variables that are incorporated into a unified construct and also allow for examination of abstract, socially or psychologically created constructs that cannot be directly measured (Bollen, 2002). For Research Questions 1 and 2, correlations and regressions among latent variables of decision making (intuitive and deliberative), socio-emotional and cognitive control processes, age (as an observed variable), and the various dependent variables (some latent and some observed) were examined. For Research Question 3, latent variable interactions between the independent variables (sensation seeking, reward sensitivity, emotional reactivity and cognitive control) and the

moderators (self-regulation and deviant peers) predicting risk behaviors were examined. To specify a latent variable interaction in Mplus, the TYPE=RANDOM command must be used to identify random variables (Muthén & Muthén, 1998-2010). When a significant interaction occurred, the simple slopes were estimated using the MODEL CONSTRAINT command. This command allows new parameters to be defined. The simple slopes were defined as the main effect + the interaction effect at one standard deviant above or below the moderator.

CHAPTER 3: RESULTS

Preliminary Analyses

Descriptive statistics of study variables are given in Table 1. See Appendix B for frequencies of categorical variables. Correlations among latent and single item study variables are given in Table 2. Correlations showed that deliberative decision making was positively correlated with self-regulation, resistance to peer influence, future orientation, and age and negatively correlated with sensation seeking, deviant peers, general risk, delinquency, substance use, and smoking. Intuitive decision making was positively correlated with emotional reactivity, future orientation, and resistance to peer influence but not to any other variables at the bivariate level. Results of regressions with demographic variables predicting study variables are shown in Table 3. Generally, Asian participants were less likely than other race/ethnicities to engage in risk behaviors. Individuals who lived in a Greek house or off-campus with roommates were more likely than those living elsewhere to engage in risk behavior. Women were more likely to engage in both types of decision making, had higher emotional reactivity, future orientation, resistance to peer influence and self-regulation whereas men were more likely to engage in risk behaviors, had higher levels of sensation seeking and reward sensitivity.

Measurement of socio-emotional and cognitive control processes. For socio-emotional processing, the model did not converge with the three scales (sensation seeking, reward sensitivity, and emotional reactivity) as indicators or as a higher-order factor with the three scales as intermediate factors. The model was then tested with two indicators of emotional reactivity (based on the scales scores of the AIM and Mood

Survey, respectively). This model converged, but sensation seeking did not load significantly onto the latent socio-emotional factor. When sensation seeking was removed, reward sensitivity no longer loaded onto the latent factor. Therefore, in order to test the remaining hypotheses, the three indicators of the socio-emotional system were modeled as separate latent variables in the primary analyses (Figure 5a-c).

For cognitive control (Figure 6), punishment sensitivity did not load onto the latent variable, perhaps because the constructs involved in punishment sensitivity are not deliberative in nature. The three remaining indicators, self-regulation, resistance to peer influence, and future orientation loaded significantly as scale scores onto a latent cognitive control variable which was used in the primary analyses. However, the model is just identified so no fit statistics are available. See Table 4 for all CFA results including fit statistics and added correlated errors of final measures and latent factors.

Table 1.

Descriptive Statistics of Study Variables

Variable	Mean	Standard Deviation	Min.	Max.	Skewness	Kurtosis
Deliberative decision making	3.75	.48	2.10	5.00	-.13	.01
Intuitive decision making	3.41	.47	1.60	5.00	-.39	1.12
Sensation seeking	3.63	.71	1.17	5.00	-.36	.26
Reward sensitivity	2.88	.49	1.50	4.30	.00	.13
Emotional reactivity	3.68	.53	2.31	5.38	.39	-.07
Future orientation	4.04	.53	2.27	5.00	-.42	-.12
Resistance to peer influence	2.97	.46	1.40	4.00	-.38	.25
Self-regulation	3.71	.45	2.40	5.00	.52	.51
Deviant peers	2.29	.66	1.00	4.36	.48	-.02
Delinquency (square root)	.36	.36	.00	1.45	.84	.21
Tobacco use (square root)	.72	.89	.00	9.00	.89	-.56
Cigarette use	1.77	2.84	.00	9.00	1.54	1.02
Alcohol use	4.35	2.87	.00	9.00	-.26	-1.45
Drunk driving (square root)	.46	.73	.00	2.83	1.39	.82
Marijuana use (square root)	.83	1.07	.00	3.00	.87	-.73
Number of sexual partners	2.73	1.62	.00	5.00	.31	-1.51
Lack of condom use	2.21	1.38	1.00	5.00	.82	-.70
Age	19.25	1.33	17.00	24.0	1.05	.61

Table 2.

Correlations among Latent and Single Item Study Variables.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Deliberative decision making	-.06	-.33**	.00	.06	.58**	.14*	.63**	-.29**	.15*	-.34**	-.22**	-.35**	-.14*	-.10	-.10	-.08	.02	.02
2. Intuitive decision making	-	.12	.12	.14*	.22*	.15*	.06	-.04	-.03	-.03	-.02	-.07	.08	-.01	.03	-.14*	.09	.09
3. Sensation seeking		-	.32**	-.01	-.08	-.03	-.08	.38**	-.22**	.45**	.34**	.41**	.21*	.20*	.24**	.08	-.04	-.02
4. Reward sensitivity			-	.26**	.07	-.35**	-.18*	.37**	.01	.40**	.25**	.42**	.26**	.26**	.14*	.30**	.12	.03
5. Emotional reactivity				-	-.01	-.24**	-.27**	.01	-.07	-.03	-.11*	-.01	.01	-.12*	-.03	.02	.02	-.02
6. Future orientation					-	.23**	.63**	-.14*	-.01	-.14*	-.04	-.17*	-.07	-.04	-.10	-.16*	.04	.02
7. Resistance to peer infl.						-	.53**	-.11	.11	-.12	-.09	-.23*	-.04	-.09	-.04	-.13*	.02	.04
8. Self-regulation							-	-.18*	.08	-.22**	-.05	-.31**	-.13*	-.05	-.16*	-.21**	-.05	-.05
9. Deviant peers								-	.00	.84**	.66**	.65**	.53**	.63**	.50**	.68**	.34**	.07
10. Age									-	.09	.07	-.09	.01	.08	.12*	.03	.20**	.04
11. Risk										-	-	-	-	-	-	-	-	-
12. Substance use											-	.43**	-	-	-	-	.31**	.05
13. Smoking												-	.30**	.32**	.43**	.08	.09	.18*
14. Alcohol use													-	-	.41**	.41**	.23**	-.04
15. Drunk driving														-	.28**	.28**	.17*	.01

16. Marijuana use			-	.47**	.11	.04
17.Delinquecy				-	.17*	-.12
18. # partners					-	.22**
19. Lack of condom use						-

Note: *$p < .05$, **$p < .001$. Correlations between latent variables and their indicators were not included.

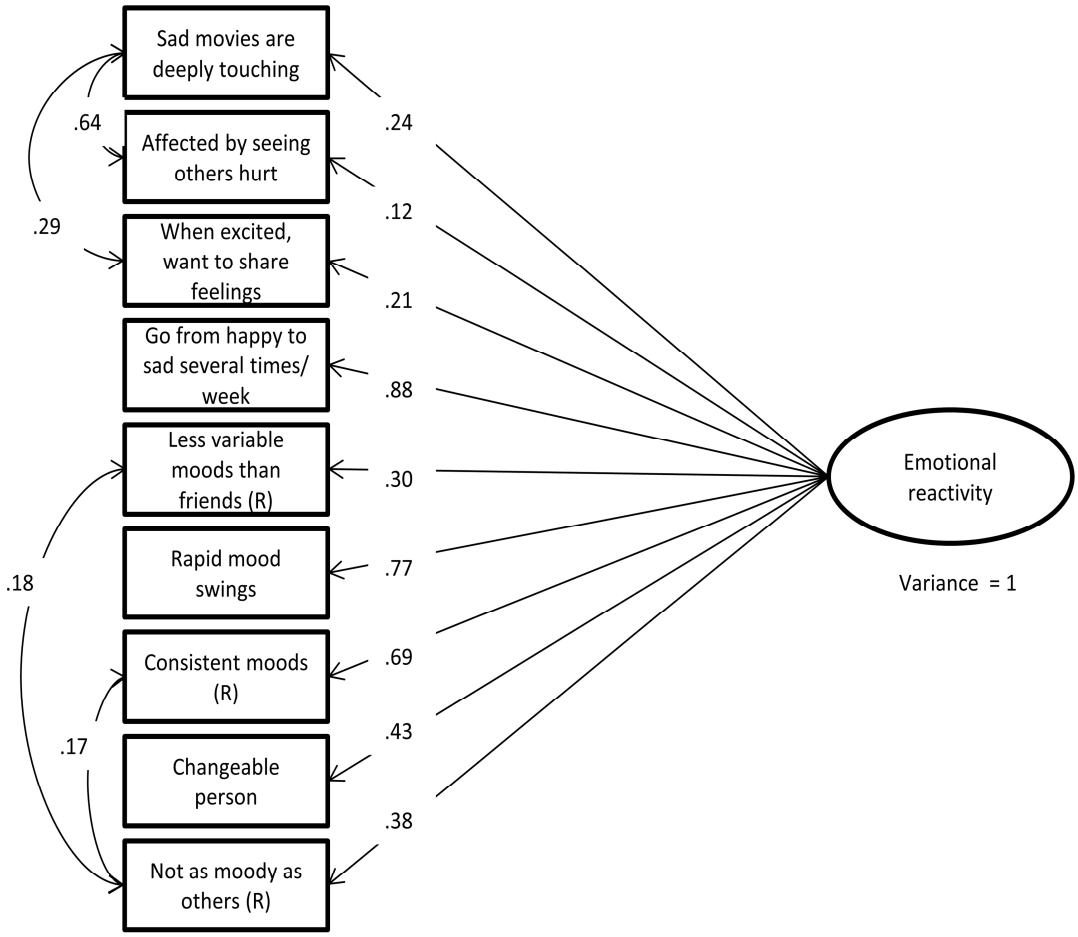
Table 3.

Standardized Results of Demographic Regressions

	Race (dummy coded – Whites are reference group)		Residence (dummy coded – On-campus is reference group)						
Variable	Black/Latino/ Biracial	Asian	Greek House	Off-campus	Off-campus with family	Sex	Parent Education	Parent Occupation	Family Income
Deliberative DM	.10	.05	.09	.02	.18*	.13*	.09	.08	.01
Intuitive DM	.01	-.07	.06	-.01	-.12	.23**	.05	-.07	.02
Sensation seeking	-.17*	.00	-.02	-.09	-.17*	-.17*	-.11	-.04	.06
Reward sensitivity	-.15	.08	.08	-.05	-.01	-.26*	-.07	.12	.05
Emotional reactivity	.00	.18**	-.07	-.10	-.07	.11*	.08	.04	-.15*
Future orientation	.00	-.10	.14*	.10	.00	.32**	.09	.00	.00
Resistance to peer influence	.12	-.12	.11	.11	.09	.12*	.16*	-.13	-.11
Self-regulation	.00	-.14*	.14*	.12	.10	.15*	.05	.00	.03
Deviant peers	-.06	-.19**	.16*	.14*	-.04	-.20**	-.08	-.07	.06
Risk	-.07	-.21**	.29**	.28**	.01	-.19*	-.07	-.02	.08
Substance use	-.09	-.21**	.32**	.26**	-.04	-.07	-.04	-.04	.13*
Delinquency	.00	.02	.24*	.01	-.11**	-.28**	-.09	.04	-.03
Smoking	-.11**	-.10	.10*	.17*	.08	-.13*	-.09	.02	.00
Alcohol Use	-.09	-.21**	.32**	.27**	-.04	-.05	-.04	-.05	.15*
Drunk driving	-.10*	-.15**	.15*	.28**	-.01	-.09	.01	-.08	.02
Marijuana use	.04	-.13*	.22**	.14*	.08	-.18**	-.01	.00	.10
Other drug use	-.09*	-.08*	.06	.15*	.06	-.15*	-.01	.04	-.03
# partners	.08	.07	-.17*	.19*	.27**	.03	-.13	.07	-.11
Condom use	.02	-.14	-.13*	.09	.08	.06	-.03	.06	-.02

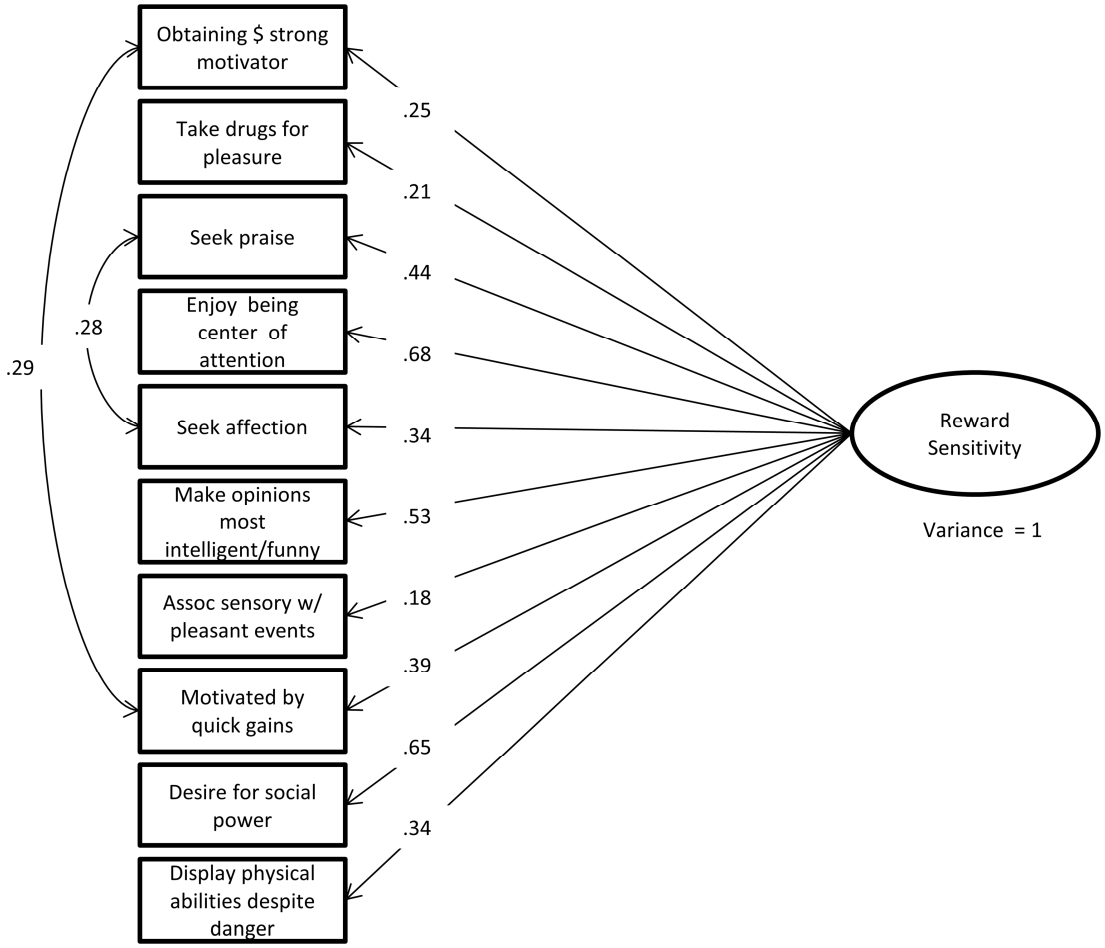
Note: $^{*}p < .05$, $^{**}p < .001$.

Figures 5a-c. Confirmatory factor analysis results of socio-emotional system constructs



Note: All factor loadings are standardized and significant at $p < .05$

Figure 5a. Confirmatory factor analysis results of emotional reactivity



Note: All factor loadings are standardized and significant at $p < .05$

Figure 5b. Confirmatory factor analysis results of reward sensitivity

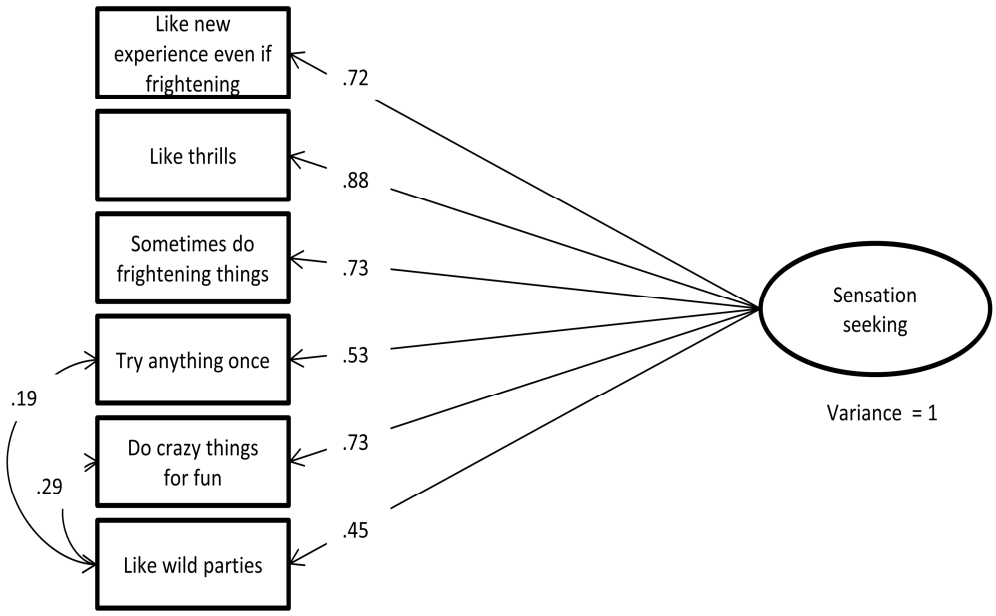


Figure 5c. Confirmatory factor analysis results of sensation seeking

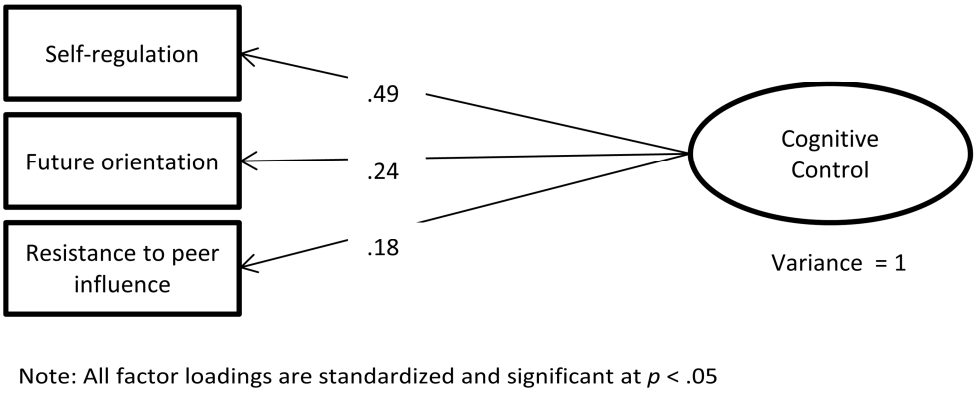


Figure 6. Confirmatory factor analysis results of cognitive control

Table 4.

Results of Confirmatory Factor Analyses

Scale	χ^2	df	CFI	RMSEA	SRMR	Stndrd Factor Loadings	Correlated Errors Added
Deliberative Decision Making	45.28	27	.97	.04	.04	.45-.62*	Think through decisions WITH Think before act; Clear reasons for decisions WITH Think before act
Intuitive Decision Making	61.13	31	.95	.05	.04	.29-.68*	Rely on feelings WITH Feelings important in decisions; Instincts decide action WITH Not rely intuition decs (r); Not rely intuition decs(r)WITH Foolish make decs feelings(r); Instincts decide action WITH Listen to deep feelings;
Sensation Seeking	23.34	7	.98	.08	.03	.45-.88*	Like wild parties WITH Do crazy things for fun; Like wild parties WITH Try anything once;
Reward Sensitivity	72.73	33	.91	.06	.05	.18-.68*	Obtain $$ strong motivator WITH Motivated by quick gains; Seek praise WITH Seek affection;
Emotional Reactivity	62.98	23	.94	.07	.05	.12-88*	Sad movies deeply touching WITH Affected by others hurt; Sad movies deeply touching WITH If excited, share feelings; Less variable moods than friends WITH Not moody as others; Less variable moods than friends WITH Consistent moods;
Resistance to Peer Influence	64.02	34	.95	.05	.04	.21-.67*	More important to be individual rather than with crowd WITH Better to be individual than make others angry;
Self-Regulation	200.17	100	.92	.05	.05	.34-.69*	Track progress of goals WITH Set goals and track progress; Only make mistakes once WITH Don't learn from mistake (r); Hard to set goals (r) WITH Trouble plans to reach goals (r); Realize effects of actions too late (r)WITH Don't notice actions someone points out (r);
Future Orientation	73.03	31	.95	.06	.04	.44-.76*	Think about things in future WITH How often think of plans; Achieve goals worth effort WITH How likely achieve goals; Achieve goals worth effort WITH Effect of personal effort;

Deviant Peers	113.15	31	.94	.08	.05	.37-.80*	How often think about plans WITH Collect info about plans; Frnds used non-prescrip drugs WITH Frnds used other drugs; Friends unprotected sex WITH Friends has multiple partners; Friends stole WITH Friends hit others; Friends cheat on tests WITH Friends encourage law-breaking;
General Risk (without drug use and ever had sex)	40.38	14	.96	.07	.04	.19-.77*	
Substance Use (without drug use)	32.44	14	.99	.06	.04	.33-.97*	
Alcohol Use	2.94	2	1.00	.04	.01	.58-.97*	

Note: * $p < .05$. Results are estimated with maximum likelihood with robust standard errors.

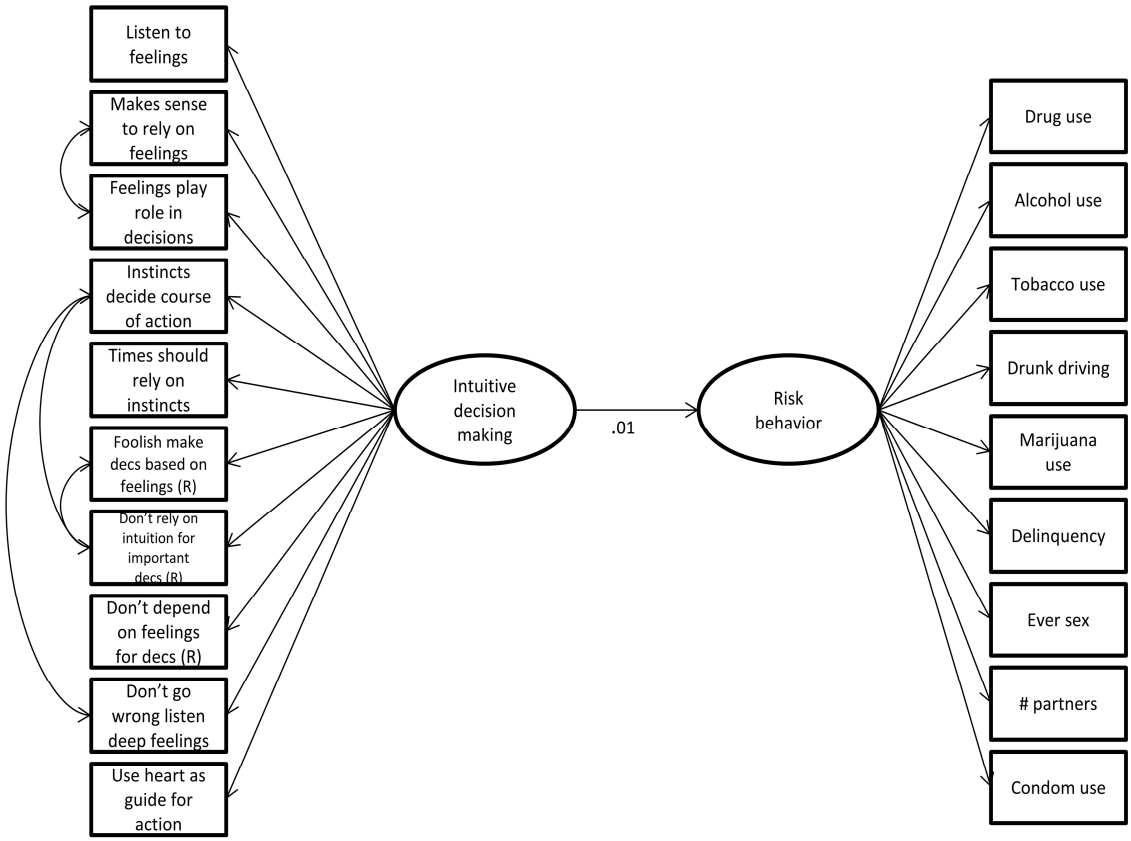
Primary Analyses

For the primary analyses, SEMs were estimated to determine the structural paths among latent variables of interest. Measurement portions of the models remained the same as described in the Measures section except that one factor loading in each measure was fixed to 1.0 in order to freely estimate the variance of the latent factor. For models with drug use as the dependent variable, a logistic regression was estimated whereas linear regressions were estimated for all continuous dependent variables.

Research Question 1. Research Question 1 asked about the relations between neurobiological processes and dual-process decision making models as well as the relations between decision making and age. To test Hypothesis 1, the relation between the three latent socio-emotional variables and latent intuitive decision making were estimated. The covariance (unstandardized path coefficient) was not significant for sensation seeking (b = .12, SE = .06, p = .06), reward sensitivity (b= .01, SE = .01, p = .12), or emotional reactivity (b = .01, SE = .01, p = .07); thus Hypothesis 1 was not supported. It should be noted that the relatively low factor loadings for some of these measures may indicate poor measurement of the constructs. For Hypothesis 2, the covariance between the latent cognitive control processes and latent deliberative decision making was significant (b = .29, SE = .03, p < .001), suggesting that individuals who scored higher on cognitive control measures also tended to engage in deliberative decision making. Hypothesis 2 was supported. For Hypothesis 3, the covariance between latent intuitive and deliberative decision making and age were each examined. Age was not related to intuitive decision making (b = -.03, SE = .06, p = .57) but was related to deliberative decision making (b = .14, SE = .06, p < .05), suggesting that older

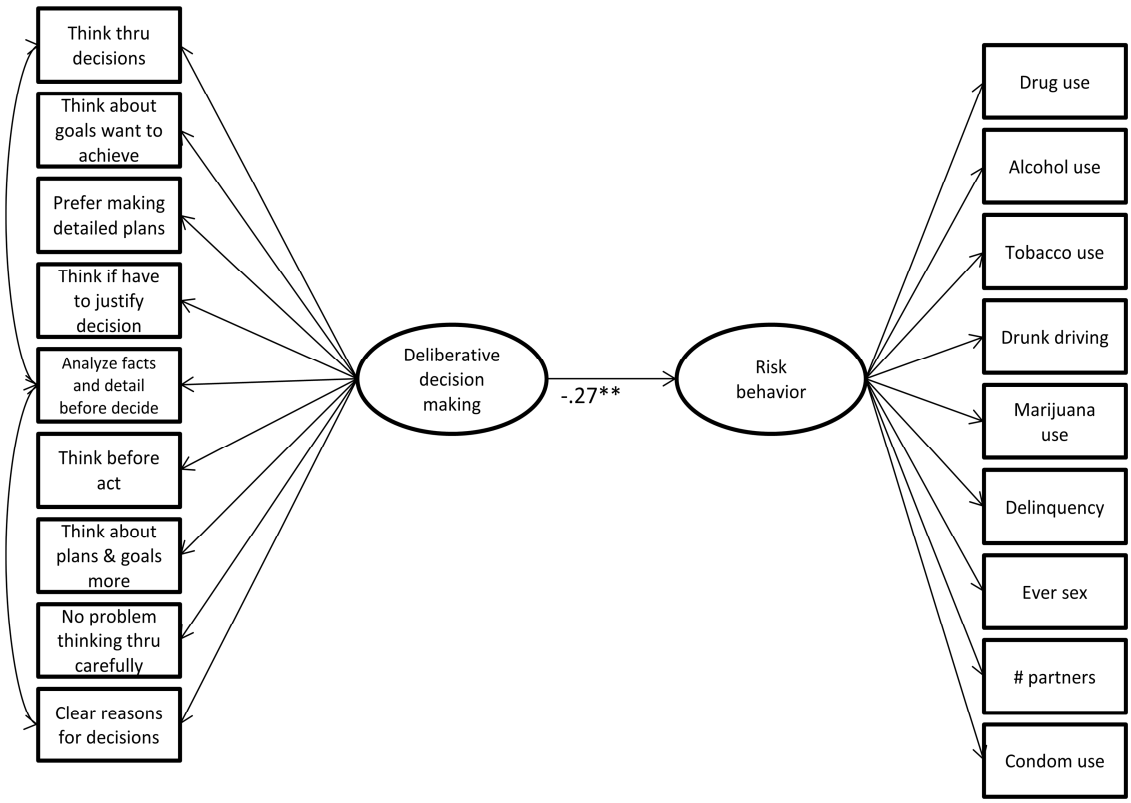
individuals were more likely to engage in deliberative decision making, partially supporting Hypothesis 3.

Research Question 2. For Hypotheses 4a and 4b the relations between latent intuitive and latent deliberative decision making (separately) and risk behavior were tested in a regression format so that the demographic variables could be included as controls on risk behavior. As described above, each type of risk behavior and the latent general risk behavior variable were used as dependent variables. Intuitive decision making was not related to any of the risk behaviors, so Hypothesis 4b was not supported. Figure 7 depicts the relation between latent intuitive decision making and latent general risk behavior. For ease of interpretation, in the figure, only the estimate for the relationship between the two latent variables is shown, excluding the factor loadings and correlated errors. In the regressions including deliberative decision making, decision making was related to less general risk behavior as well as lower levels of all the other risk indicators except for the two sexual risk taking items (lack of condom use and number of sexual partners), partially supporting Hypothesis 4a. See Figure 8 for the relation between deliberative decision making and general risk behavior and Table 5 for a summary of model results.



Note: *$p < .05$ **$p < .001$. Factor loadings are all significant. The range of estimates and fit statistics are provided in Table 4.

Figure 7. Structural model of intuitive decision making and risk behavior.



Note: *$p < .05$ **$p < .001$. Factor loadings are all significant. The range of estimates and fit statistics are provided in Table 4.

Figure 8. Deliberative decision making and risk.

Table 5.

Summary of the Relations between Decision Making Process and Risk

Path	Correlation	Standard Error
Intuitive decision making → General risk	.01	.06
Intuitive decision making → Substance use	.00	.06
Intuitive decision making → Alcohol use	-.03	.05
Intuitive decision making → Drug use	-.14 (odds ratio= .31)	.02
Intuitive decision making → Marijuana use	-.04	.06
Intuitive decision making → Cigarette Use	.07	.06
Intuitive decision making → Delinquency	-.02	.07
Intuitive decision making → Lack of Condom Use	.09	.07
Intuitive decision making → # partners	.08	.07
Deliberative decision making → General risk	-.27**	.06
Deliberative decision making → Substance use	-.25**	.06
Deliberative decision making → Alcohol use	-.16*	.05
Deliberative decision making → Drug use	-.19* (odds ratio=.36)	.09
Deliberative decision making → Marijuana use	-.19*	.06
Deliberative decision making → Cigarette Use	-.19*	.06
Deliberative decision making → Delinquency	-.24**	.06
Deliberative decision making → Lack of Condom Use	-.06	.07
Deliberative decision making → # partners	-.10	.07

Note: *$p < .05$ **$p < .001$.

Research Question 3. Research Question 3 involved the role of self-regulation in moderating the relations between socio-emotional processes and risk behavior and the role of deviant peers in moderating the relations between socio-emotional and cognitive control processes and risk behavior.

The moderating role self-regulation. For Hypothesis 5, an interaction between latent self-regulation and each latent socio-emotional variable was tested to assess the moderating effect of self-regulation on the relations between socio-emotional processes and risk behavior. For the models with sensation seeking as the independent variable, four significant interactions emerged: predicting overall risk behavior (b = -1.13, SE = .48, $p < .05$), substance use (b = -.21, SE = .10, $p < .05$), delinquency (b = -.10, SE = .03, $p < .01$), and smoking (b = -1.21, SE = .60, $p < .05$). Analysis of the simple slopes for latent risk behavior, substance use, and smoking revealed that higher levels of sensation seeking were related to more risk behavior at both high and low levels of self-regulation, but this was especially true at lower levels of self- regulation (See Table 6 for estimates). For delinquency, the simple slope pattern was similar. More sensation seeking was related to higher levels of delinquency at lower levels of self-regulation but unrelated at higher levels of self-regulation. Figure 9a shows the path diagram of the interaction with both simple effects and the interaction path. The measurement models and controls are not shown. Figure 9b shows the pattern of the interaction in which individuals with higher sensation seeking and lower self-regulation are more likely to engage in delinquent behaviors. The slope of the line depicting lower self-regulation is positive and significant; the slope for higher self-regulation is non-significant (see Table 6 for estimates). The simple effect of sensation seeking was significant in each model except it

did not predict lack of condom use or number of sexual partners; the simple effect of self-regulation was also significant such that higher levels of self-regulation predicted lower levels of general risk behavior, substance use, smoking, marijuana use, and delinquency. See Table 6 for full results.

When reward sensitivity and emotional reactivity were the independent variables, only one interaction, reward sensitivity by self-regulation predicting delinquency, was significant (b = -.25, SE = .10, $p < .05$). The pattern was that higher reward sensitivity was related to more delinquency for those with lower self-regulation (b = .19, SE = .07, $p < .05$) but not for those with higher self-regulation (b = -.05, SE = .03, p = .11) (similar to Figures 9a and 9b). The simple effect of reward sensitivity was positively related to risk behaviors except for drug use, lack of condom use, and number of sexual partners. The simple effect of self-regulation in the model with reward sensitivity was negative and significant for general risk behavior, marijuana use, substance use, smoking, and delinquency.

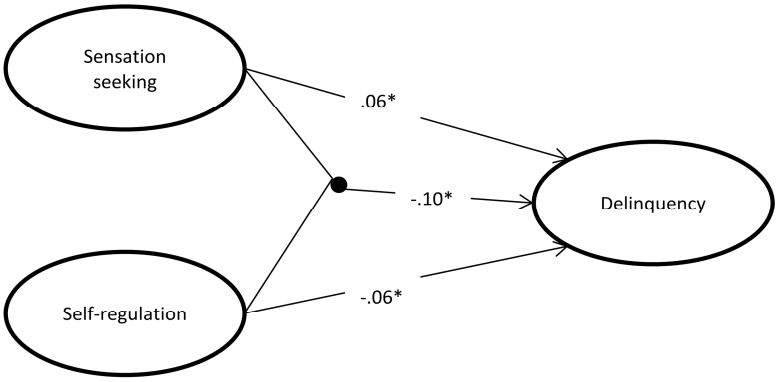
The simple effect of emotional reactivity was not significant for any risk behaviors whereas the simple effect of self-regulation when in the model with emotional reactivity was negative and significant for all risk behaviors except the sexual risk taking items. Hypothesis 5 was partially supported, and the interaction that was significant was in the expected direction, which showed that the relation between reward sensitivity and delinquency was positive at low levels of self-regulation and non-significant at high levels of self-regulation. In other words, self-regulation buffered the effect of reward sensitivity on delinquency. See Table 6 for full results.

Table 6.

Summary of Results for Interactions between Latent Self-Regulation and Socio-Emotional Variables

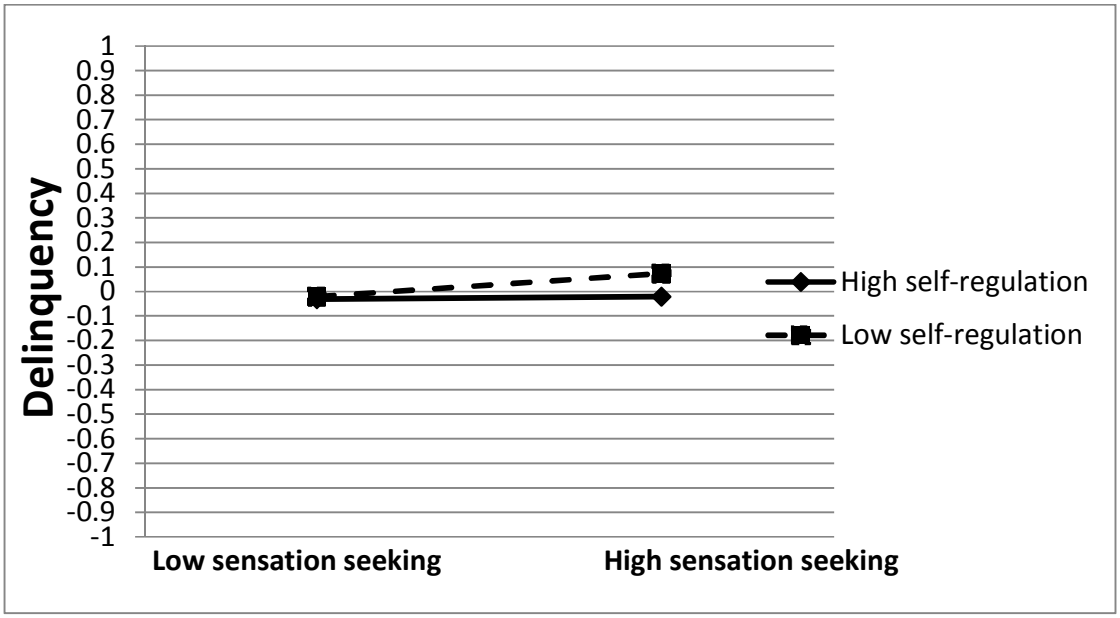
Sensation seeking X self-regulation	Simple effect of sensation seeking (SE)	Simple effect of self-reg (SE)	Interaction (SE)	Simple slope at high self-reg (SE)	Simple slope at low self-reg (SE)
General Risk	1.84(.39)**	-1.14(.31)**	-1.13(.47)*	1.21(.38)*	2.08(.50)**
Substance Use	.38(.06)**	-.22(.06)**	-.21(.10)*	.29(.07)**	.48(.09)**
Alcohol use	.25(.05)**	-.08(.05)	-.05(.08)	-	-
Delinquency	.05(.02)*	-.05(.02)*	-.09(.03)*	.01(.01)	.09(.03)*
Cigarette Use	1.85(.35)**	-.80(.34)*	-1.21(.60)*	1.29(.42)*	2.41(.46)**
Marijuana Use	.55(.12)**	-.52(.13)**	-.38(.22)	-	-
Other Drug Use	1.83(.53)*	-.77(.54)	-.64(1.00)	-	-
Lack of Condom	.32(.20)*	-.16(.20)	.57(.34)	-	-
# Partners	.42(.22)	-.23(.22)	-.14(.37)	-	-
Reward sensitivity X self-regulation	Simple effect of reward sensitivity (SE)	Simple effect of self-reg (SE)	Interaction (SE)	Simple slope at high self-reg (SE)	Simple slope at low self-reg (SE)
General Risk	2.00(.69)*	-1.05(.32)*	-1.56(.94)	-	-
Substance Use	.37(.13)*	-.21(.06)*	-.30(.21)	-	-
Alcohol use	.24(.10)*	-.05(.05)	-.02(.17)	-	-
Delinquency	.06(.03)*	-.03(.01)*	-.17(.07)*	-.02(.02)	.14(.05)*
Cigarette Use	2.07(.80)*	-.72(.35)*	-1.58(1.29)	-	-
Marijuana Use	.60(.26)*	-.49(.13)**	-.79(.45)	-	-
Other Drug Use	1.40(.89)	-.88(.47)	-1.17(1.68)	-	-
Lack of Condom	.27(.41)	-.23(.20)	1.04(.80)	-	-
# Partners	.61(.48)	-.25(.23)	.37(.81)	-	-
Emotional reactivity X self-regulation	Simple effect of emot reactivity (SE)	Simple effect of self-reg (SE)	Interaction (SE)	Simple slope at high self-reg (SE)	Simple slope at low self-reg (SE)

General Risk	.43(.47)	-1.16(.35)*	-.07(.93)	-	-
Substance Use	.08(.10)	-.23(.07)*	-.01(.20)	-	-
Alcohol use	-.04(.08)	-.11(.05)*	.02(.16)	-	-
Delinquency	-.01(.02)	-.05(.02)*	-.01(.04)	-	-
Cigarette Use	.49(.58)	-.68(.37)*	-.45(1.16)	-	-
Marijuana Use	.20(.21)	-.53(.14)*	-.40(.42)	-	-
Other Drug Use	1.18(.73)	-1.05(.45)*	1.43(1.59)	-	-
Lack of Condom	.07(.33)	-.22(.21)	.54(.67)	-	-
# Partners	.39(.38)	-.20(.24)	1.52(.84)	-	-



Note: Measurement model results given in Table 4; *$p < .05$ **$p < .001$

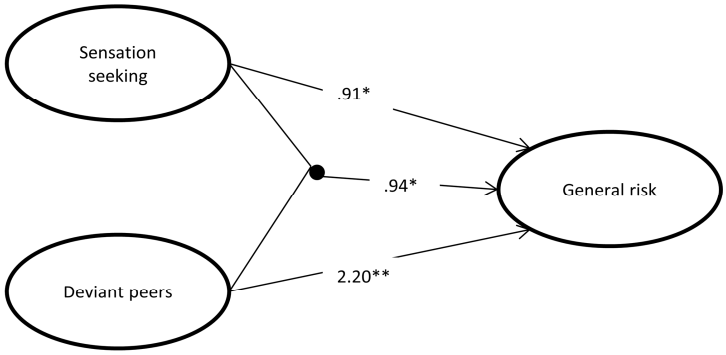
Figure 9a. *Path diagram for interaction between latent sensation seeking and self-regulation predicting delinquency*



Note: Slope for those with higher self-regulation is non-significant. High self-regulation and sensation seeking was defined as 1 standard deviation above the mean and low self-regulation and sensation seeking was 1 standard deviation below the mean.

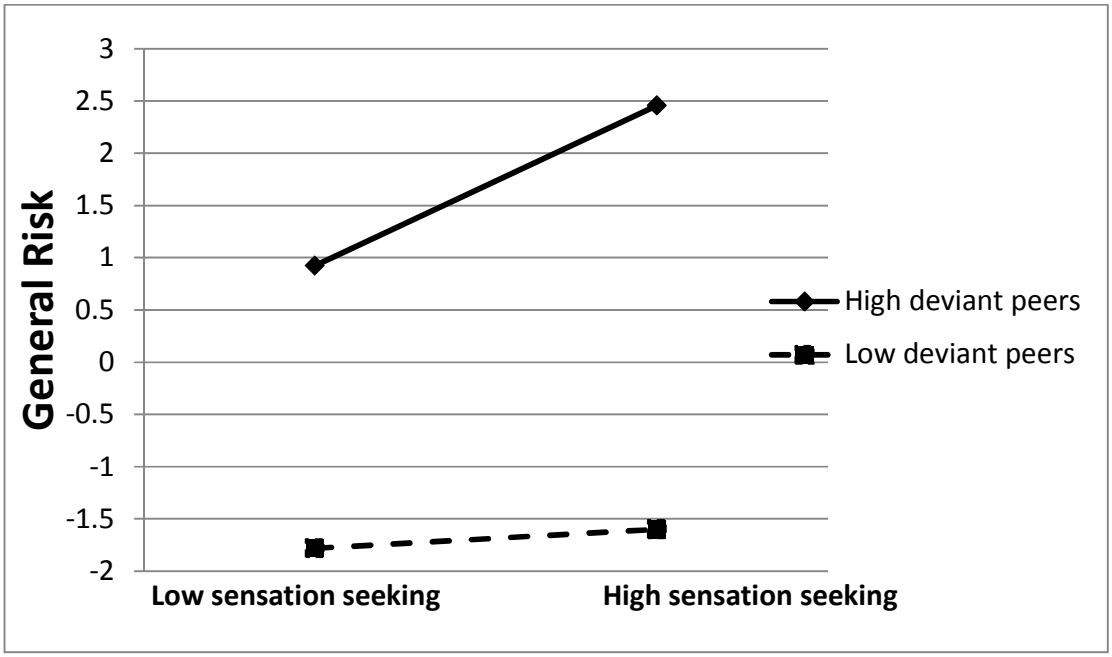
Figure 9b. *Graph for simple slopes depicting the interaction between sensation seeking and self-regulation predicting delinquency.*

The moderating role of deviant peers. Hypothesis 6 stated that having deviant peers would moderate the relations between socio-emotional processes and risk behavior as well as cognitive control and risk behavior. With sensation seeking as the independent variable, there was a significant interaction between sensation seeking and deviant peers for general risk behaviors (b = .1.01, SE = .32, p < .01), delinquency (b = .10. SE = .01, p < .001), substance use (b = .18, SE =.07, p < .05), marijuana use (b = .49, SE = .16, p < .05), and smoking (b = 1.97, SE = .46, p < .001). Examination of simple slopes indicated that sensation seeking was positively related to general risk behavior for those with more deviant peers but there was no significant relationship for those with fewer deviant peers (See Figures 10a and 10b). A similar pattern was found for substance use, marijuana use, and smoking. Simple slopes in the model predicting delinquency showed that there was a stronger positive relationship between sensation seeking and delinquency for those with more deviant peers than for those with fewer deviant peers. Overall, deviant peers exacerbated the relationship between sensation seeking and risk behaviors. Furthermore, the simple effect of deviant peers was positively related to all risk behaviors except lack of condom use, and the simple effect of sensation seeking was positively related to general risk behaviors, delinquency, substance use, marijuana use and smoking. See Table 6 for full results.



Note: Measurement model results given in Table 4; *$p < .05$ **$p < .001$

Figure 10a. *Path diagram for latent interaction between sensation seeking and deviant peers predicting risk behavior*



Note: Slope for those with lower deviant peers is non-significant. High deviant peers and sensation seeking was defined as 1 standard deviation above the mean and low deviant peers and sensation seeking was 1 standard deviation below the mean.

Figure 10b. *Graph for simple slopes depicting the interaction between sensation seeking and self-regulation predicting delinquency.*

Regarding the relation between reward sensitivity and risk behavior, there was a significant interaction between reward sensitivity and deviant peers predicting alcohol use (b = -.23, SE = .11, p < .05) and smoking (b = 2.00, SE = 1.01, p < .05). Examination of simple slopes showed a positive relation between reward sensitivity and smoking for adolescents with higher deviant peer affiliation, but more alcohol use for those with lower deviant peer affiliation. The models predicting delinquency and marijuana use never converged so those results are not included. The simple effect of deviant peers was positive and significant for all risk behaviors (although estimates were not available for delinquency and marijuana use) and reward sensitivity was positive and significant for general risk behavior. See Table 6 for full results.

With emotional reactivity as the independent variable, only one interaction emerged: the interaction between emotional reactivity and deviant peers predicted delinquency (b = - .08, SE = .04, p < .05). For individuals with fewer deviant peers, higher emotional reactivity was not related to delinquency (b = .05, SE = .03, p > .05), whereas for those with more deviant peers, higher emotional reactivity was related to more delinquency (b = .07, SE = .03, p < .05), similar to Figure 10b. The simple effect of deviant peers was once again related to all dependent variables, whereas emotional reactivity was not related to any.

Finally, the interaction between cognitive control and deviant peers was tested. Deviant peers moderated the relationship between cognitive control and risk behavior (b = -.39, SE = .16, p < .05) substance use (b = -.07, SE = .03, p < .05), marijuana use (b = -.22, SE = .09, p < .05), and delinquency (b = -.06, SE = .01, p < .001). For general risk, substance use and marijuana use the analysis of the simple slopes showed that more

cognitive control was related to less use for those with more deviant peers and there was no relationship between cognitive control and risk for those with fewer deviant peers. For delinquency, more cognitive control was related to less delinquency for those with more deviant peers, but positively related to delinquency for those with fewer deviant peers. The simple effect of cognitive control was negatively related to general risk, substance use, marijuana use and delinquency whereas the simple effect of deviant peers was positively related to all risk behaviors. See Table 6 for full results.

In summary, Hypothesis 6 regarding the moderating effect of deviant peers on the socio-emotional and cognitive control systems was partially supported. When in models with socio-emotional processes, deviant peers exacerbated the positive effect of socio-emotional constructs on risk behavior. The models with cognitive control showed that for those with more deviant peers cognitive control was negatively related to risk. Having fewer deviant peers, however, was related to a positive relationship between cognitive control and delinquency.

Table 7.

Summary of Results for Interactions between Latent Deviant Peer Affiliation and Neurobiological Systems

Sensation seeking X deviant peers	Simple effect of Sensation seeking (SE)	Simple effect of deviant peers (SE)	Interaction (SE)	Simple slope at high dev peers (SE)	Simple slope at low dev peers (SE)
General Risk	1.03(.28)**	2.16(.38)**	1.01(.32)*	1.81(.45)**	.26(.27)
Substance Use	.19(.05)**	.43(.05)**	.18(.07)*	.33(.08)**	.06(.06)
Alcohol use	.10(.05)	.29(.04)**	-.06(.05)	-	-
Delinquency	.04(.00)**	.04(.00)**	.10(.01)**	.11(.01)**	.04(.00)**
Cigarette Use	1.38(.35)**	1.77(.26)**	1.97(.46)**	2.90(.58)**	-.14(.41)
Marijuana Use	.25(.12)	.90(.10)**	.49(.16)*	.63(.19)*	-.13(.14)
Other Drug Use	.94(.83)	2.71(.60)**	.53(1.26)	-	-
Lack of Condom	.23(.21)	.29(.20)	.32(.39)	-	-
# Partners	.13(.23)	.92(.24)**	-.07(.41)	-	-
Reward sensitivity X deviant peers	Simple effect of Reward sens (SE)	Simple effect of deviant peers (SE)	Interaction (SE)	Simple slope at high dev peers (SE)	Simple slope at low dev peers (SE)
General Risk	.71(.48)	2.35(.43)*	.54(.56)	-	-
Substance Use	.06(.09)	.47(.05)**	.05(.12)	-	-
Alcohol use	.02(.08)	.31(.04)**	-.23(.11)*	-.15(.11)	.20(.11)*
Delinquency	-	-	-	-	-
Cigarette Use	1.27(.72)	1.91(.28)**	2.00(1.01)*	2.81(1.31)*	-.27(.73)
Marijuana Use	-	-	-	-	-
Other Drug Use	-1.07(1.25)	2.97(.61)**	3.55(2.01)		
Lack of Condom	.10(.42)	.39(.21)	-.78(.73)	-	-
# Partners	.20(.46)	.91(.24)**	-.07(.74)	-	-
Emotional reactivity X deviant peers	Simple effect of Emot reactivity (SE)	Simple effect of deviant peers (SE)	Interaction (SE)	Simple slope at high dev peers (SE)	Simple slope at low dev peers (SE)

General Risk	.41(.37)	2.45(.44)**	-.32(.47)	-	-
Substance Use	.07(.07)	.48(.05)**	-.05(.10)	-	-
Alcohol use	-.06(.06)	.31(.04)**	-.10(.09)	-	-
Delinquency	-.01(.01)	.07(.02)**	-.08(.04)*	.07(.03)*	.05(.03)
Cigarette Use	.34(.49)	2.13(.27)**	-1.69(.71)	-	-
Marijuana Use	.21(.17)	.97(.12)**	.24(.24)	-	-
Other Drug Use	1.87(1.36)	3.05(.58)**	-.32(1.67)	-	-
Lack of Condom	.05(.45)	.37(.19)*	.10(.55)	-	-
# Partners	.20(.35)	.91(.22)**	.25(.59)	-	-
Cognitive control X deviant peers	Simple effect of Cog control (SE)	Simple effect of deviant peers (SE)	Interaction (SE)	Simple slope at high dev peers (SE)	Simple slope at low dev peers (SE)
General Risk	-.31(.12)*	2.34(.42)**	-.39(.16)*	-.61(.19)*	-.02(.13)
Substance Use	-.05(.02)*	.47(.05)**	-.07(.03)*	-.10(.03)*	.00(.03)
Alcohol use	.01(.02)	.30(.04)**	.01(.03)	-	-
Delinquency	-.04(.00)**	.05(.00)**	-.06(.01)**	-.09(.01)**	.01(.00)**
Cigarette Use	-.14(.14)	2.06(.27)**	-.31(.20)		
Marijuana Use	-.17(.06)*	.92(.12)**	-.22(.09)*	-.34(.10)*	-.02(.07)
Other Drug Use	-.13(.36)	3.04(.57)**	-.41(.50)	-	-
Lack of Condom	.06(.09)	.31(.19)*	.10(.17)	-	-
# Partners	-.01(.10)	1.13(.28)**	.01(.22)	-	-

Summary of primary results. Deliberative decision making was positively related to cognitive control and age and negatively related to many risk behaviors. Intuitive decision making was not related to socio-emotional processes, age, or risk behaviors. Self-regulation moderated some of the relations between socio-emotional processes and risk behavior showing that higher self-regulation was protective against the negative influences of socio-emotional variables. Having deviant peers was a consistently strong predictor of risk behavior and having more deviant peers exacerbated the relations between the socio-emotional system and risk behavior. Having more deviant peers also strengthened the negative relations between cognitive control and risk behavior.

CHAPTER 4: DISCUSSION

The primary purpose of the current study was to further explore the relation between decision making and risk behavior among college students. First, the overlap between more traditional dual-process decision making models and constructs described as part of the neurobiological model of adolescent decision making and risk-taking was examined. Specifically, analyses examined the relations between intuitive decision making and socio-emotional processing as well as deliberative decision making and cognitive control processing. Furthermore, the relationship between age and each decision making process was assessed to determine if there might be a developmental aspect to dual-process models, which to date have generally lacked a developmental focus. Previous investigations into age differences of decision making have tended to focus on specific heuristics, fallacies, and cognitive abilities. The present research also attempted to strengthen the neurobiological model by incorporating real-world risk behaviors and by identifying individual difference factors that may moderate the relations between the constructs relating to the socio-emotional and cognitive control systems of the neurobiological model and risk behaviors. In general, support was found linking cognitive control processes and deliberative decision making to each other and also to risk behaviors, consistent with hypotheses. However, intuitive decision making was not related to socio-emotional variables or risk behaviors, not supporting hypotheses. Furthermore, self-regulation and deviant peers moderated the relations between neurobiological systems and risk behaviors.

Research Question 1: Associations between Neurobiological Systems and Dual-processes

The first research question was whether dual-process decision making models and the neurobiological theory could be related. The current study found that measures of deliberative decision making and cognitive control system variables (self-regulation, future orientation, and resistance to peer influence) were indeed related. This was expected because the deliberative process of dual-process decision making models and the cognitive control system of the neurobiological theory both refer to more analytical, logical, computational, decision making (Kahneman, 2003; Klaczynski, 2005; Steinberg, 2008). Previous research has shown that, in terms of cognitive *abilities*, such as logical reasoning, adolescents were similar to adults, suggesting that development of cognitive abilities is generally complete by mid-adolescence (Steinberg, 2007). So it is important to distinguish deliberative decision making, which involves some regulatory capacity, from concepts like abstract reasoning abilities. If maturation of the prefrontal cortex underlies cognitive control development, perhaps it also underlies the development of deliberative decision making. Conceptualization of the neurobiological model should include deliberative decision making.

The results also provided information on the components of cognitive control. Cognitive control was comprised of three constructs: self-regulation, future orientation, and resistance to peer influence. To my knowledge, these have not been previously related to deliberative decision making. The ability to control one's behaviors, emotions, and attention in order to meet one's goals, to make complex plans for the future, and to resist friends' potentially negative influences help a person make good decisions. Punishment sensitivity was originally hypothesized to be a part of cognitive control because it would presumably inhibit poor decision making. However, punishment

sensitivity was not related to the other three constructs. This may be due to the mechanism of inhibition involved in punishment sensitivity. For instance, the punishment sensitivity measure included items such as fear, embarrassment, and shyness. Although these constructs are inhibitory, they are perhaps more representative of emotions and temperament than cognitive control. The present finding is perhaps in contrast with a study which found that attentiveness to punishment in the context of the Iowa Gambling Task increased linearly with age parallel with other cognitive control constructs. In the present study, a paper and pencil measure was used and results indicated that it was not related to other cognitive control constructs. This could be due to different types of measures (survey vs. behavioral) actually measuring different tendencies or it could be that punishment sensitivity, while related to age, should not be conceptualized as related to cognitive control and is instead indicative of a different developmental process, such as a decline in the propensities of the socio-emotional system. So perhaps the decline in risk behavior in adulthood is not only because the cognitive control system has caught up with the socio-emotional system, but also due to a decrease of the socio-emotional system.

The relations between intuitive decision making and socio-emotional processing were also examined. None of the constructs hypothesized as part of the socio-emotional system was related to intuitive decision making. Thus, it may be concluded that socio-emotional processes and intuitive decision making do not appear to overlap. It is possible that because intuitive decision making is so common for every day decisions it is not predictive of any particular subset of decisions whereas socio-emotional processing is meant to describe risky decision making in particular. Although both the intuitive decision making process and socio-emotional system operate quickly and outside of

conscious thought (Kahneman, 2003; Klaczynski, 2005), intuitive decision making reflects common decision making as opposed to the socio-emotional system which reflects reward and novelty seeking specifically. Therefore, it is important to keep the concepts of intuition and socio-emotional processing separate in research on decision making.

An important point, however, is that a latent factor of socio-emotional processing did not materialize because the three hypothesized constructs, which were sensation seeking, reward sensitivity, and emotional reactivity, did not load onto a single factor. The issue apparently was with emotional reactivity, which was not correlated at the bivariate level with reward sensitivity or risk behaviors. The items included in the emotional reactivity measure were meant to reflect intensity and variation in mood or emotions and were included because risky decisions are thought to be strongly influenced by emotions. It is unclear whether the fault is with the operationalization of emotional reactivity or the conceptualization of the role that emotions play in the socio-emotional system. Perhaps emotional reactivity would have accounted for more variance and fit with the other measures in a younger age group when the mismatch between the socio-emotional system and cognitive control is at its peak.

Also posed in Research Question 1 was whether the decision making processes would be related to age. Due to the cross-sectional nature of this study, change over time could not be addressed. However, correlations with age did imply that older individuals were more likely to endorse deliberative decision making than younger individuals. Intuitive decision making, on the other hand, was not related to age in the present sample. Again, this could be because the majority of decisions are made intuitively throughout

adulthood. In fact, as the number of decisions a person has to make on their own increases (presumably with age and experience) the intuitive decisions should perhaps increase out of necessity to conserve mental energy. A mature decision maker, as defined by the self-regulation model of decision making, is one who knows when a decision is worthy of deliberation (Byrnes, 2005). Perhaps it is not the use of intuitive processing that changes with age, but rather *which decisions* are made with the intuitive process. Such a relationship, of course, would not be reflected in a correlation with age. Another possibility is that a college sample is too old to show changes in socio-emotional processing or intuitive decision making. The largest gap between the socio-emotional system and the cognitive control system is thought to occur earlier in adolescence (Steinberg, 2007; Steinberg, 2008). Perhaps the socio-emotional system and intuitive processing are related earlier in adolescence. The socio-emotional system is thought to develop quickly in mid-adolescence and may be fully developed and have reached a plateau or declined by the time individuals reach college.

In sum, we learned that deliberative decision making is related to, and should be included in conceptions of, cognitive control, and that it is related to age. Additionally, intuitive processing is separate from socio-emotional processing and is not related to age. Furthermore, the components of the socio-emotional system may need re-conceptualization or may not be appropriate for a college-aged sample. Replication of the current results in other age ranges is needed to confirm or refute these claims.

Research Question 2: Neurobiological Constructs and Risk Behavior

Research Question 2 concerned whether the decision making processes were related to risk behaviors. Deliberative decision making was negatively related to most

risk behavior, suggesting that those who are more likely to think through decisions are less likely to decide to engage in risk behaviors. This finding corroborates some previous research on the relationship between deliberative decision making and risk behaviors (e.g., Beyth-Marom et al., 1993; Wolff & Crockett, 2011). This is in contrast to fuzzy trace theory, which has suggested that, because the likelihood of negative consequences is relatively low, verbatim-type processing would lead individuals to make the rational choice to engage in risk behavior (Reyna et al., 2005). It is possible, and seems likely, that deliberative decision making involves more than weighing risk and rewards and choosing a course of action based only on the likelihood of a negative consequence. Rather, deliberative decision making would take multiple aspects of a decision into account, including the severity of a negative consequence and thinking about alternative courses of action. Intuitive decision making was not related to risk behavior, which, although the relation was hypothesized, is unsurprising, since it was not related to socio-emotional processes. This, again, is in contrast with fuzzy trace theory, which contends that the fuzzy, gist-based conception of the potential for a catastrophe would prevent someone from making the decision to engage in risk behavior. Much of research on fuzzy trace decision making is on behavioral tasks where participants must decide whether to gamble as the probabilities of winning become less and less likely (Reyna et al., 2005). So the differences in the fuzzy trace theory and the present findings may be in how intuitive processing is measured.

An important exception to the relations between deliberative decision making and risk behavior is that the two sexual risk taking items, not using condoms and number of sexual partners, were unrelated to deliberative decision making. This suggests that the

decision making process may be different for these items or for sexual behavior more broadly. Although using condoms is the safest option (other than abstinence) to protect oneself against sexually transmitted infections (STIs), it is possible that a monogamous couple where both partners have been tested for STIs would be practicing safe sex using another type of contraceptive, such as birth control pills. Furthermore, personal decision style may not be the same as dyadic decision making style or the partner's decision making style (see also Wolff & Crockett, 2011). A more varied and exhaustive assessment of sexual risk taking, such as one proposed in Turchik and Garske (2009), in which many more behaviors, such as sexual intent, sex while under the influence of drugs and alcohol, and regretted or unexpected sexual encounters are assessed, may be better able to determine which decision making process helps or harms young people in terms of sexual risk taking.

Research Question 3: The Moderating Effect of Self-regulation and Deviant peers

The third research question had to do with the influence of individual and contextual differences in self-regulation and deviant peers on the relationship between socio-emotional and cognitive control processing and risk behavior. In this study, self-regulation had two roles: one as part of the cognitive control system that is thought to increase with age; the other as an individual difference variable which may make participants more or less susceptible to socio-emotional processes. Self-regulation is a broad construct that is measureable in very early in childhood and tends to increase throughout childhood and adolescence (Kopp, 1982). Yet, self-regulation also shows stability over time. One study found that individual differences in self-regulation were relatively stable from ages 4 or 5 to ages 12 or 13 (Raffaelli et al., 2005). In the present

study, only a few interactions with self-regulation were significant. For those that were found, self-regulation buffered the negative effect of socio-emotional constructs on risk behavior as predicted. Therefore, individual differences in self-regulation may affect the trajectory of the socio-emotional system.

The relative lack of significant interactions could point to measurement issues with the socio-emotional processes. The simple effect of self-regulation was generally significant in predicting risk behaviors, except it did not predict sexual risk taking and only predicted alcohol use in the model with emotional reactivity. It is conceivable that drug use and delinquency are more "serious" risk behaviors that occur less among college students than alcohol use and sexual risk taking and therefore self-regulation may be an important predictor for the "serious" risk behaviors as opposed to the more "normative" risk behaviors like alcohol use and sexual risk taking among college students.

Affiliating with deviant peers was a more reliable predictor of risk behaviors, replicating much previous research (Brown, 2004; Hawkins et al., 1992; Dishion et al., 1995). Interactions between deviant peers and the neurobiological constructs were relatively common. Generally, there was a stronger relationship between socio-emotional processes and risk behavior for those who claimed to have more deviant peers. In other words, deviant peers exacerbated the positive relationship between socio-emotional processes and risk behavior. This finding is in agreement with the neurobiological theory which suggests that the socio-emotional system is highly activated in the presence of peers. When one's friends are participating in deviant behaviors, individuals may be inclined to follow suit. Once again the sexual risk taking outcomes were not predicted by

significant interactions. Since socio-emotional processes were unrelated to those outcomes, it was perhaps unlikely that deviant peers would moderate that relationship.

For cognitive control, the pattern of interactions was puzzling in some respects. Participants who had more deviant peers showed a negative relationship or lack of relationship between cognitive control and risk as predicted. However, those with fewer deviant peers showed a positive relationship between cognitive control and risk behavior, which was not expected. For those who had more deviant friends compared to those with fewer, it is possible that in situations involving risk behavior, the cognitive control system is activated, decreasing the relationship with risk behaviors. For those who did not claim to have deviant peers, the direction of the effect of cognitive control on risk behavior switched, becoming significant and positive. Perhaps those with higher cognitive control but few deviant friends to influence them make a more conscious decision to engage in risk behavior, consistent with the fuzzy trace theory. In other words, the idea that people make a logical decision to engage in risk behavior may only be true in the specific context of having fewer deviant friends. Perhaps in the current sample, many individuals did not have many deviant peers or they were the instigators of the behavior.

Implications

Theory. The current study has important implications for several theories of decision making, most notably the neurobiological theory. The cognitive control system and the deliberative decision making process of more traditional dual-process decision making theories appear to overlap considerably. They are each negatively related to risk behavior and positively related to each other. The socio-emotional process of the

neurobiological model, however, appears separate from intuitive decision making. Perhaps intuitive decision making which is extremely common for all decisions would not pick up on socio-emotional system constructs which are theorized to relate to risky decisions specifically. Also, it is possible that areas of the brain involved in cognitive control should also relate to deliberative decision making. Furthermore, it is now clear that individual differences need to be examined and included along with developmental changes in research on the neurobiological theory. This is important because researchers should distinguish among young people in terms of their propensity for risk behavior as certainly some are more at risk than others. Not all young people are taking part in risk behaviors and it is important to determine factors that are related to increased and decreased levels of risk.

This study also has implications for the fuzzy trace theory. The fuzzy trace theory has suggested that individuals who use gist-based processing are less likely to make risky decisions because they imagine the possibility of a catastrophe. Although the current study did not directly assess gist or verbatim processing, the measures of "gist-like" processing (i.e., intuitive decision making) were not related to risk behaviors. Additionally, "verbatim-type" processing, which is more analytical, was related to less risk taking, not more, as hypothesized by fuzzy trace theory. One potential reason for this is that most studies of fuzzy trace theory use lab tasks, such as the Iowa Gambling Task, and although some have shown that gambling tasks are related to real-world risk behavior (see Reyna & Farley, 2006; Reyna et al., 2011), there may be still be important differences between risk taking in the lab and real-time, real-world decision making in risky contexts. One recent study combined the fuzzy trace and neurobiological theories

to look at risk behavior and framing effects (a classic decision making task) (Reyna et al., 2011). Using a sample of high school and college students, measures of sensation seeking, behavioral inhibition, gist processing, and verbatim processing were measured. Results showed that once sensation seeking and behavioral inhibition were controlled, gist and verbatim processing still accounted for unique variance in sexual risk taking. So there may be important differences in the fuzzy trace constructs and the neurobiological constructs such that each account for variance in adolescent and young adult risk behavior once the other is controlled. Additionally, because the current study found a positive relationship between risk behaviors and cognitive control for those with fewer deviant peers, an important consideration for decision making and risk taking is the context in which one is making the decisions.

The self-regulation model of decision making and other models of step-wise decision making (see Beyth-Marom & Fischhoff, 1997; Byrnes, 2005) are strengthened by the current findings. These theories suggest that good decision making occurs when one approaches a decision by following a series of steps, congruent with analyzing and deliberating. If it is agreed that avoiding the risk behaviors that were assessed in this study constitutes a "good" decision, then better decision making is achieved by self-regulation and deliberation in accord with these theories.

Application. The present findings have implications for public policy as well. "Understanding the [decision making capacities], and the neural underpinnings of these processes, should be a high priority for those interested in the physical and psychological well being of young people" (Steinberg, 2008, p.19-20) Past programs intended to improve adolescent decision making have generally not fared well (see Steinberg, 2008).

According to Steinberg, the increase of cognitive control and the decrease of risk behavior will occur naturally with age, so rather than attempting to change how adolescents view or think about risky behavior, more needs to be done at the macro level to limit the opportunities for engaging in dangerous activities. For example, effective ways to deter risk taking involve policy actions such as raising the price of cigarettes and limiting access to alcohol. However, the present findings suggest that if a program was able to effectively increase deliberative decision making, it would perhaps also help young people learn to make better decisions about risk behavior. Also, improving self-regulation would help counteract socio-emotional tendencies. The current study implies that we cannot completely discount programs targeted at individual decision making.

Limitations

The present study should be considered in light of several limitations. First, the sample used was a college sample that ranged in age from 18 to 24, which may have been too old to provide an ideal test of the mismatch between the socio-emotional and cognitive control systems. The neurobiological model states that the age at which the largest gap between the socio-emotional system and the cognitive control system occurs several years earlier; therefore the current study may have only picked up on changes in the cognitive control system as the socio-emotional system may have finished developing.

The study was not longitudinal so we cannot directly assess the developmental nature of these cognitions and behaviors. Therefore we cannot know whether there is within-person change in decision making and cognitive control and if increases in cognitive control are related to decreases in risk behavior.

All measures were self-report carrying the potential for bias in participants' responses and shared method variance. Indeed there was not much variability in some of the risk behaviors measured, and the present findings could be strengthened by targeting a riskier group or using different modeling techniques to account for non-normal sample distributions in the analyses.

Finally, the sample was predominantly white and all were enrolled in college. The findings may not be applicable to the experiences of other ethnicities and individuals who did not attend college after high school. Indeed the experiences of a young adult in the workforce are likely to be different from those of a young adult in a college setting. The college environment is predisposed to exposing young people to new points of view and perhaps different ways of thinking. Additionally, college students may have more opportunities for risk behavior as they have relatively fewer responsibilities and more access to college-related phenomena, such as fraternity parties.

Future Directions

This research opens many avenues for future studies which may delve more deeply into the topics presented in this study. For example, future endeavors can include other types of individual differences in decision making and risk behavior. For example, future research on this topic should include biological aspects such as genetics and brain activation studies. There are several genes that are likely to play a role in risk behavior and cognition, such as dopamine receptor and transporter genes. Also, gene-environment interactions, which are so clearly important for understanding human behavior may help further untangle the issues of decision making about risk behavior. For instance, genes that are associated with higher levels of reward seeking may be activated in the presence

of deviant peers. These types of studies may be able to discern also whether inhibitory responses and analytical competence have different underlying mechanisms that could help further explain what prevents young people from engaging in risk behavior.

Behavioral measures and biological measures should be included along with self-report questionnaires. Some examples of behavioral measures are the Tower of London, which assesses planning, or video games like the one presented in Gardner and Steinberg (2005) which may provide better assessment of risk propensities that one may not be aware of or choose to report in a survey. Behavioral measures also provide the opportunity for studying brain activation while the participant is actually making risky decisions. One example of such a study occurred when brain imaging was assessed during the Stoplight task video game in which participants had to choose whether to run a yellow light in order to get to a party as quickly as possible (as described in Gardner and Steinberg (2005)). Results showed that reward valuation and social cognition areas of the brain were activated in decisions to stop at the red light after participants had been excluded by peers presumably because participants had heightened sensitivity to what their peers were thinking and a stronger desire for the reward that comes from impressing or pleasing their peers (Peake, Pfeifer, Stormshak, & Dishion, 2012).

There may also be other individual and social differences that would moderate the relationship between decision making processes and risk behaviors. For instance, parenting, in terms of the quality of the parent-child relationship or autonomy granting, affects risk behaviors such as delinquency as well as deviant peer affiliation (see Deutsch, Crockett, Wolff, & Russell, in press) and may also influence decision making. A recent study of Chinese adolescents found that adolescents who engaged in every day decision

making showed improvement on the Iowa Gambling Task compared to adolescents whose parents made decisions for them (Xiao et al., 2011), suggesting that parental autonomy granting may help facilitate maturation of decision making abilities. Similarly, different types of friends or differing qualities of friendship may wield different influences. One study found that risk-taking was more likely after participants had been socially excluded during a computerized task (Peake et al., 2012). It is also likely that other environmental factors such as SES, quality of school, and neighborhood quality may influence how young people think about the decision to engage in risk behaviors. Other cognitive factors may also play a role: for example, problem solving, perspective taking, or the ability to think abstractly may influence how an individual makes decisions.

Finally, other types of decisions and other decision making styles should also be included. Decisions that may be especially pertinent in late adolescence or early adulthood include decisions about college, careers, money, and romantic relationships. To fully understand the complex nature of decision making, one must look at decisions other than only those about risk behavior. Also, the dual-process models presented in this study include the two paths of individual decision making. However, there are other ways that decisions are made. For example, one may defer to another person to make their decisions or one may avoid making a decision altogether (Galotti, Ciner, Altenbaumer, Geerts, Rupp, & Woulfe, 2006). These other types of decisions and decision making styles would likely have different predictors than the decision making processes investigated currently.

Conclusion

This research has made important strides in understanding the mechanisms by which youth choose to engage in risk behaviors. Specifically, deliberative decision making is related to increased cognitive control processing, increased age, and less risk behavior. With this knowledge, we can better provide suggestions for prevention and policy designed to decrease risk behaviors. Future research studies should continue to address individual differences and translation of brain and laboratory research into real world problems. Furthermore, this study has merged various literatures that inform risk behavior research including developmental, social, and cognitive areas. This type of interdisciplinary research is essential for understanding complex problems like decision making and risk behavior.

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Appendix A

List of Items in Questionnaire
*Indicates items used in analyses

Decision Making: 1(Strongly Disagree) to 5 (Strongly Agree)

1. *Before making decisions I first think them through.
2. *I listen carefully to my deepest feelings.
3. *Before making decisions I usually think about the goals I want to achieve.
4. *With most decisions it makes sense to completely rely on your feelings.
5. I do not like situations that require me to rely on my intuition.
6. *I prefer making detailed plans rather than leaving things to chance.
7. I prefer drawing conclusions based on my feelings, my knowledge of human nature, and my personal experience.
8. *My feelings play an important role in my decisions.
9. I am a perfectionist.
10. *I think about a decision particularly carefully if I have to justify it.
11. When it comes to trusting people, I can usually rely on my gut feelings.
12. * When I have a problem I first analyze the facts and details before I decide.
13. *I think before I act.
14. I prefer emotional people.
15. *I think about my plans and goals more than other people do.
16. I am a very intuitive person.
17. I like emotional situations, discussions, and movies.
18. I try to avoid situations that require thinking in depth about something.
19. I'm not that good at figuring out complicated problems.
20. I enjoy intellectual challenges.
21. I am not very good at solving problems that require careful logical analysis.
22. I don't like to have to do a lot of thinking.
23. I enjoy solving problems that require hard thinking.
24. Thinking is not my idea of an enjoyable activity.
25. I am not a very analytical thinker.
26. Reasoning things out carefully is not one of my strong points.
27. I prefer complex problems to simple problems.
28. Thinking hard and for a long time about something gives me little satisfaction.
29. I don't reason well under pressure.
30. I am much better at figuring things out logically than most people.
31. I have a logical mind.
32. I enjoy thinking in abstract terms.
33. *I have no problem thinking things through carefully.
34. Using logic usually works well for me in figuring out problems in my life.
35. Knowing the answer without having to understand the reasoning behind it is good enough for me.
36. *I usually have clear, explainable reasons for my decisions.
37. Learning new ways to think would be very appealing to me.
38. Using my gut feelings usually works well for me in figuring out problems in my life.
39. I believe in trusting my hunches.

40. Intuition can be a very useful way to solve problems.
41. *I often go by my instincts when deciding on a course of action.
42. I trust my initial feelings about people.
43. If I were to rely on my gut feelings, I would often make mistakes.
44. *I think there are times when one should rely on one's intuition.
45. *I think it is foolish to make important decisions based on feelings.
46. *I don't think it is a good idea to rely on one's intuition for important decisions.
47. *I generally don't depend on my feelings to help me make decisions.
48. *I hardly ever go wrong when I listen to my deepest gut feelings to find an answer.
49. I would not want to depend on anyone who described himself or herself as intuitive.
50. My snap judgments are probably not as good as most people's.
51. *I tend to use my heart as a guide for my actions.
52. I can usually feel when a person is right or wrong, even if I can't explain how I know.
53. I suspect my hunches are inaccurate as often as they are accurate.

Sensation Seeking: 1(Strongly Disagree) to 5 (Strongly Agree)

1.* I like to have new and exciting experiences and sensations even if they are a little frightening.
2. *I like doing things just for the thrill of it.
3. *I sometimes like to do things that are a little frightening.
4. *I'll try anything once.
5.* I sometimes do 'crazy' things just for fun.
6.* I like wild and uninhibited parties.

Risk Behavior: 0 (Never or not in past year) to 9 (Every day or almost every day)

1. *How often have you smoked cigarettes?
2. *How often have you used smokeless tobacco?
3. *How often have you drunk alcohol (beer, wine, liquor)?
4. *How often have you had 5 or more drinks in a row?
5. *How often have you gotten drunk?
6. *How often have you driven a vehicle while drunk?
7. *How often have you used marijuana?
8. *How often have you used cocaine?
9. *How often have you used inhalants?
10. *How often have you used any other type of illegal drug?
11. *Have you ever engaged in sexual intercourse?
    - Yes
    - No

If you answered "yes," please answer the following questions.
If you answered "no," please skip to question 16

12. *How many sexual partners have you had in your lifetime?
1 (One) to 5 (More than 4)
13. *How often do you (or your partner) use a condom when you have sex?
1 (always) to 5 (Never)
14. How often do you (or your partner) use another type of contraception (diaphragm, sponge, jelly, etc.) when you have sex?

15. How often do you (or your partner) use hormone-based contraception (birth control pills, Depo-Provera, NuvaRing, etc.)
16. *How often have you painted graffiti on someone else's property or in a public place? 0 (Never or not in past year) to 7 (About once a week)
17. *How often have you deliberately damaged property that didn't belong to you?
18. *How often have you taken something from a store without paying for it?
19. *How often have you driven a car without its owners' permission?
20. *How often have you gone into a house or building to steal something?
21. How often have you used or threatened to use a weapon to get something from someone?
22. *How often have you sold marijuana or other drugs?
23. *How often have you stolen something worth less than $50?
24. *How often have you acted loud, rowdy, or unruly in a public place?
25. *How often have you taken part in a fight where a group of your friends was against another group of friends?
26. How often have you been arrested?

Deviant peers: 1(None) to 5 (Almost all)

1. *How many of your friends got drunk?
2. *How many of your friends smoked cigarettes?
3. *How many of your friends tried drugs other than those for which they had a prescription?
4. *How many of your friends used inhalants, marijuana, or other drugs (other than alcohol or cigarettes)?
5. *How many of your friends had sex without a condom/birth control?
6. *How many of your friends had sex with more than one partner?
7. How many of your friends were involved in student organizations/teams?
8. *How many of your friends stole something worth less than $50?
9. *How many of your friends hit or threatened to hit someone for no reason?
10. How many of your friends do or have done volunteer work?
11. How many of your friends ruined or damaged other people's things or school property on purpose?
12. How many of your friends broke into a place like a car or building to steal something?
13. How many of your friends stole something worth more than $50?
14. How many of your friends are or have been involved as leaders at school (e.g., extracurricular activities, student governments, etc)?
15. How many of your friends disapprove of using drugs or alcohol?
16. *How many of your friends cheated on school tests?
17. *How many of your friends suggested that you do something that is against the law?
18. How many of your friends get good grades?

Sensitivity to Reward and Punishment: 1(Never) to 5 (Always)

1. Do you often refrain from doing something because you are afraid of it being illegal?
2. *Does the good prospect of obtaining money motivate you strongly to do some things?
3. Are you often afraid of new or unexpected situations?
4. Is it difficult for you to telephone someone you do not know?
5. *Do you like to take some drugs because of the pleasure you get from them?

6. *Do you often do things in order to be praised?
7. Are you troubled by punishments at home or in school?
8. *Do you like being the center of attention at a party or a social meeting?
9. In tasks that you are not prepared for, do you attach great importance to the possibility of failure?
10. Are you easily discouraged in difficult situations?
11. *Do you need people to show their affection for you all the time?
12. Are you a shy person?
13. *When you are in a group, do you try to make your opinions the most intelligent or the funniest?
14. Whenever possible, do you avoid demonstrating your skills for fear of being embarrassed?
15. When you are with a group, do you have difficulties selecting a good topic to talk about?
16. Whenever you can, do you avoid going to unknown places?
17. Do you like to compete and do everything you can to win?
18. Are you often worried by things that you said or did?
19. *Is it easy for you to associate tastes and smells to very pleasant events?
20. Is there a large number of objects and sensations that remind you of pleasant events?
21. Do you, on a regular basis, think that you could do more things if it was not for your insecurity or fear?
22. *Do you sometimes do things for quick gains?
23. Comparing yourself to people you know, are you afraid of many things?
24. Do you often find yourself worrying about things to the extent that performance in intellectual abilities is impaired?
25. Do you often refrain from doing something you like in order not to be rejected or disapproved of by others?
26. *Would you like to be a socially powerful person?
27. Do you often refrain from doing something because of your fear of being embarrassed?
28. *Do you like displaying your physical abilities even though this may involve danger?

Emotional reactivity: 1(Never) to 6 (Always)

1. When I accomplish something difficult I feel delighted or elated.
2. I feel pretty bad when I tell a lie.
3. My heart races at the anticipation of some exciting event.
4. *Sad movies deeply touch me.
5. My friends might say I'm emotional.
6. *The sight of someone who is hurt badly affects me strongly.
7. When I succeed at something, my reaction is calm contentment.
8. *When I am excited over something, I want to share my feelings with everyone.
9. * I may change from happy to sad and back again several times in a single week.
10. I'm frequently "down in the dumps."
11. *Compared to my friends, I'm less up and down in my mood states.
12. *Sometimes my moods swing back and forth very rapidly.
13. *My moods are quite consistent – they almost never vary.
14. * I'm a very changeable person.
15. *I'm not as "moody" as most people I know.

Resistance to Peer Influence

*Really true for me	Sort of true of me	Some people go along with their friends just to keep their friends happy.	BUT	Other people refuse to go along with their friends want to do, even though they know it will make their friends unhappy.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people think it's more important to be an individual than to fit in with the crowd.	BUT	Other people think it is more important to fit in with the crowd than to stand out as an individual.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	For some people, it's pretty easy for their friends to get them to change their mind.	BUT	For other people, it's pretty hard for their friends to get them to change their mind.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people would do something that they knew was wrong just to stay on their friends' good side.	BUT	Other people would not do something they knew was wrong just to stay on their friends' good side.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people hide their true opinion from their friends if they think their friends will make fun of them because of it.	BUT	Other people will say their true opinion in front of their friends, even if they know their friends will make fun of them because of it.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people will not break the law just because their friends say that they would.	BUT	Other people would break the law if their friends said that they would break it.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people change the way they act so much when they are with their friends that they wonder who they "really	BUT	Other people act the same way when they are alone as they do when they are with their friends.	Sort of true of me	Really true of me

		are."				
*Really true for me	Sort of true of me	Some people take more risks when they are with their friends than they do when they are alone.	BUT	Other people act just as risky when they are alone as when they are with their friends.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people say things they don't really believe because they think it will make their friends respect them more.	BUT	Other people would not say things they didn't really believe just to get their friends to respect them more.	Sort of true of me	Really true of me
*Really true for me	Sort of true of me	Some people think it's better to be an individual even if people will be angry at you for going against the crowd.	BUT	Other people think it's better to go along with the crowd than to make people angry at you.	Sort of true of me	Really true of me

Self-regulation: 1(Strongly Disagree) to 5 (Strongly Agree)

1. When I'm sad, I can usually start doing something that will make me feel better.
2. If something isn't going according to my plans, I change my actions to try and reach my goal.
3. I can find ways to make myself study even when my friends want to go out.
4. When I'm bored I fidget or can't sit still.
5. I can usually act normal around everybody if I'm upset with someone.
6. I am good at keeping track of lots of things going on around me, even when I'm feeling stressed.
7. I can start a new task even if I'm already tired.
8. I lose control whenever I don't get my way.
9. Little problems detract me from my long-term plans.
10. I forget about whatever else I need to do when I'm doing something really fun.
11. If I really want something, I have to have it right away.
12. During a dull class, I have trouble forcing myself to start paying attention.
13. After I'm interrupted or distracted, I can easily continue working where I left off.
14. If there are other things going on around me, I find it hard to keep my attention focused on whatever I'm doing.
15. I never know how much more work I have to do.
16. When I have a serious disagreement with someone, I can talk calmly about it without losing control.
17. It's hard to start making plans to deal with a big project or problem, especially when I'm feeling stressed.
18. I can calm myself down when I'm excited or all wound up.
19. I can stay focused on my work even when it's dull.

20. I can stop myself from doing things like throwing objects when I'm mad.
21. I work carefully when I know something will be tricky.
22. I am usually aware of my feelings before I let them out.
23. In class, I can concentrate on the material even if other people are talking.
24. When I'm excited about reaching a goal (e.g., going to college, finishing a project), it's easy to start working toward it.
25. I can find a way to stick with my plans and goals, even when it's tough.
26. When I have a big project, I can keep working on it.
27. I can resist doing something when I know I shouldn't do it.
28.* I usually keep track of my progress toward my goals.
29. *I don't notice the effects of my actions until it's too late.
30. *I am able to accomplish goals I set for myself.
31. *I put off making decisions.
32.* It's hard for me to notice when I've "had enough" (alcohol, food, sweets).
33. * I have trouble following through with things once I've made up my mind to do something.
34.* I don't seem to learn from my mistakes.
35.* I usually only have to make a mistake one time in order to learn from it.
36. I have personal standards and try to live up to them.
37. *As soon as I see a problem or challenge, I start looking for possible solutions.
38. *I have a hard time setting goals for myself.
39. *When I'm trying to change something, I pay a lot of attention to how I'm doing.
40. *I have trouble making plans to help me reach my goals.
41.* I set goals for myself and keep track of my progress.
42. I can usually find several different possibilities when I want to change something.
43. *Often I don't notice what I'm doing until someone calls it to my attention.
44. I usually think before I act.
45. *I know how I want to be.
46.* I give up quickly.

Future orientation: 1 (Never) to 5 (Always)

1. *I think about how things might be in the future.
2. *I make lists of things to do.
3. *I can see my life 10 years from now.
4. *When it comes to your educational and occupational goals for the future, to what extent are achieving those goals worth your effort? 1(Not at all) to 5 (A lot)
5. *How likely it is that you will achieve your educational and occupational goals?
6. *What effect will your personal effort have on achieving your educational and occupational goals? 1 (No effect) to 5 (A huge effect)
7. *How often do you find yourself thinking about your future educational or occupational plans?
8. *How often do you find yourself collecting information about your future educational or occupational goals?
9. *How often do you talk to others about the future?
10. *I am making serious preparation for my future education or occupation. 1(Strongly disagree) to 5(Strongly Agree)
11. *I have clear plans for achieving my future educational and occupational goals.

Appendix B

Frequencies of Categorical Variables

Drug Use	331 (86.6%) Never done drugs 49(12.8%) Done drugs
Sex	143(37.4%) Men 239(62.6%) Women
Race/Ethnicity	321(84%) White 36(9.4%) Black, Latino, Biracial 23(6.0%) Asian
Parent 1 Education	8(2.1%) less than high school education 66(17.3%) high school graduate 69(18.1%) some college 46(12.0%) Associate's degree 121(31.7%) Bachelor's degree 48(12.6%) Master's degree 24(6.3%) Doctoral degree
Parent 2 Education	12(3.1%) Less than high school education 56(14.7%) High school graduate 55(14.4%) Some college 40(10.5%) Associate's degree 113(29.6%) Bachelor's degree 57(14.9%) Master's degree 14(3.7%) Doctoral degree
Parent 1 Occupation	29(7.6%) Day laborer, etc. 23(6.0%) Painter, etc. 33(8.6%) Auto mechanic, etc. 58(15.2%) Machinist, etc. 120(31.4%) Supervisor, etc. 73(19.1%) Nurse, etc.

	13(3.4%) Veterinarian, etc. 27(7.1%) Physician, etc.
Parent 2 Occupation	19(5.0%) Day laborer, etc. 19(5.0%) Painter, etc. 35(9.2%) Auto mechanic, etc. 60(15.7%) Machinist, etc. 78(20.4%) Supervisor, etc. 74(19.4%) Nurse, etc. 23(6.0%) Veterinarian, etc. 23(6.0%) Physician, etc.
Family Income	13(3.4%) $0-15,000 15(3.9%) $15,000-30,000 32(8.4%) $30,001-45,000 46(12.0%) $45,001-60,000 49(12.8%) $60,001-75,000 54(14.4%) $75,001-90,000 62(16.2%) $90,001-105,000 97(25.4%) over $105,000
Residence	211(55.2%) On-campus dorm or apartment 49(12.8%) Greek House 91(23.8%) Off-campus, with roommates or alone 28(7.3%) With parents/guardians or other family

Note: Parent occupation is the average of the occupations given for each parent or caregiver for those with two parents or caregivers. Parent education is the average of the education levels given for each parent for those with two parents.

Appendix C

Genetic Analyses

The original intent of this study was to assess genotype as an individual difference that may have affected the relations between the socio-emotional or cognitive control system and risk behavior. However, due to contamination of the DNA samples, analyses were not performed. Specifically, the hypothesis stated: Dopamine is implicated in the reward processing and sensation seeking of the socio-emotional system, and polymorphisms of a dopamine receptor gene will be especially relevant to risk-taking. Carriers of the 7r allele of DRD4 are expected to have higher socio-emotional process scores. Furthermore, the relationship between the socio-emotional process and risk behavior will be stronger for those with the 7r allele than for those with a different variant of the DRD4 gene because prior research has shown an effect of having the 7r allele on novelty/reward seeking and some types of risk behavior.

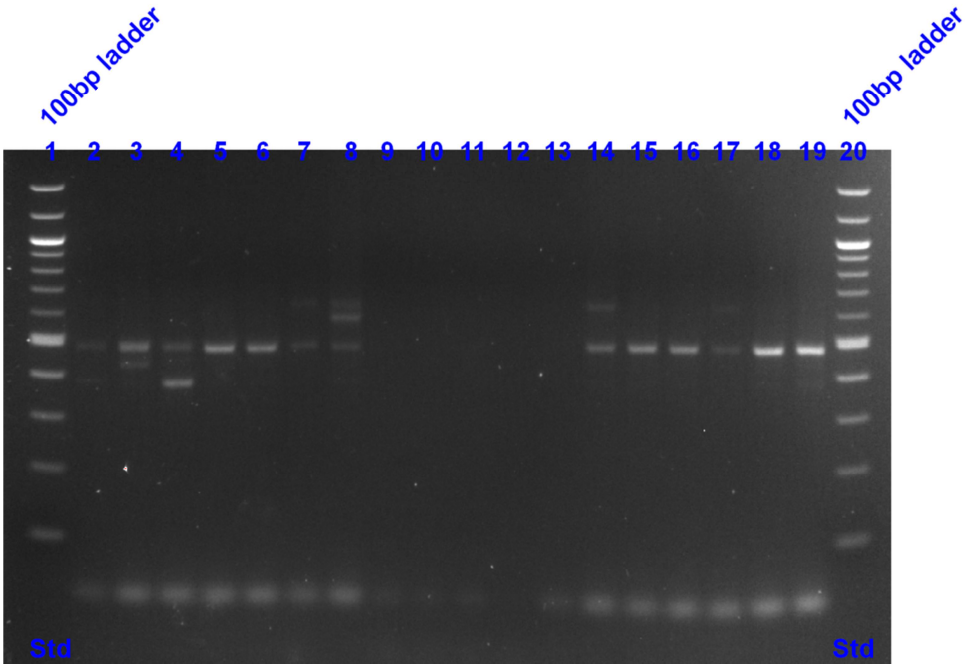
This hypothesis was based on the following: Changes in the dopamine system are mainly developmental changes that occur in everyone, but it is also likely some these changes may be more pronounced in some individuals due to their genotype. Due to the apparent increase of dopamine receptors, the dopamine receptor gene (DRD4) is a likely candidate for individual differences in changes in sensation seeking in adolescence. For example, the 7-repeat (7r) allele of the DRD4 gene has been empirically linked to reward/novelty seeking and to some risk behaviors (Becker, Laucht, El-Faddagh, & Schmidt, 2005; Laucht, Becker, & Schmidt, 2006; Laucht, Becker, Blomever, & Schmidt, 2007; Ray, Bryan, Mackillop, McGeary, Hesterberg, & Hutchison, 2009).

Further review of the literature revealed other polymorphisms that may have been genotyped had the samples been viable: The DRD4 promoter C-521T SNP appears to reduce transcriptional efficiency of the DRD4 gene in the presence of the T allele, meaning fewer receptors are made (D'Souza et al., 2004), whereas the C allele has been associated with heightened sexual arousal and sexual desire and with novelty seeking (Ben Zion et al., 2006; Okuyama, Ishiguro, Nankai, Shibuya, Watanabe, & Arinami, 2000). Perhaps individuals with the C allele, who have "typical" levels of receptors being produced are at increased risk of having more dopamine transmission compared to those without a C allele during adolescence. The catechol-o-methyl tranferase (COMT) val158met polymorphism may also play a role because the Met allele has been associated with efficient patterns of prefrontal cortical activation and superior cognitive performance (Rosa, Dickinson, Apud, Weinberger, & Elvevåg, 2010). Therefore, individuals with a Met allele of the COMT gene may show more cognitive control. Finally, the dopamine transporter, DAT1 3'VNTR, which regulates neuronal dopamine transporter proteins that are responsible for dopamine reuptake (Bazzett, 2008) has been related to impulsivity in terms of delay discounting (Paloyelis, Asherson, Mehta, Faraone, & Kuntsi, 2010). In sum, some individuals may be more or less protected from the increases in dopamine transmission during adolescence due to their genotype, and we cannot assume that brain changes are going to be standard across individuals. Polymorphisms in the regulatory regions such as BDNF or NRXN3 which are involved in neural development may be important when studying issues related to brain development.

The data collection involved participants swabbing the inside of their cheeks for 1 minute to collect a sufficient number of cells for DNA extraction. Then they returned the

swab to the research assistant who, wearing latex gloves, deposited the cells into a cell lysis solution where they were stored.

When all samples were collected, DNA was extracted by first isolating the DNA in an RNase treatment, then precipitating the protein, and finally precipitating the DNA. Effectively, this process separates the DNA from the rest of the cell material. After DNA extraction, the samples were nano-dropped, which identifies the amount DNA obtained. Next, polymerase chain reaction (PCR) was performed on the samples, which, through cycles of denaturation, annealing, and extension, amplified the candidate gene of interest for visualization. The amplified fragments were visualized on agarose gels with CybrSafe staining. The amplification process involves using electric signals to move the DNA fragments through the gel. See below for an example gel image.



In this gel image, the lane numbers 2-18 each identify a sample of DRD4. The ladders on each end are the standards. DRD4 is a variable number tandem repeat

polymorphism, which means that a sequence of 48 base pairs is repeated a certain number of times. Each allele may have 2 – 11 repeats. The higher the number of repeats, the larger the DNA fragment is, which means that a fragment does not move as far through the gel. The lines within each lane show where the fragment stopped moving and thus indicates the genotype for the sample. Sample 14 appears to have a 4-repeat allele and a 7-repeat allele. Samples 15 and 16 appear to have two 4-repeat alleles. Unfortunately, all samples contained a 4-repeat allele, which is so improbable that it indicates that the samples were all contaminated and the genetic data was not reliable.