# Do Peers Alter Decision Making Processes in Adolescence?

# An Examination of Peer Influence on Cool and Hot Executive Function.

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## Dedication

This thesis is dedicated to my aunt Nicki. From the time she taught me to read the phonetically impossible word “the,” she showed me that I could always achieve more than I believed.

## Abstract

Adolescents are overwhelmingly represented in outcomes of risk, such as drunk driving and unplanned pregnancy. Yet, teenagers possess many of the same decision making skills as adults and can accurately assess risk outcomes (Best & Miller, 2010; Furby & Beyth-Marom, 1992). Previous research has supported the premise that while general cognitive skills are only marginally impaired in adolescents when compared to adults, peers may exert a greater level of influence during adolescence regarding risky decision making compared to both childhood and adulthood (Furby & Beyth-Marom, 1992; Gardner & Steinberg, 2005). The current study investigated the effect of peer presence on decision-making using two measures of cool Executive Function [the Dimensional Change Card Sort (DCCS) test and the Attention Network (ANT) Test] and two measures of hot Executive Function [the Balloon Analogue Risk Test (BART) and the Stoplight (STOP) Test)] in a sample of younger adolescents (12-15 year olds) and older adolescents (18-21 year olds). A within subjects design was used to test performance differences in cool and hot executive function between two experimental contexts: an alone context and a peer context. A significant interaction between experimental context by age group by gender ($F(1, 86) = 11.69$, $p < .001$) in the ANT was found. Follow up Student Newman Keul's tests indicate that younger adolescent males improved on the ANT in the context of their peers. These data provide compelling support for the integration of context into the study of risk taking and decision making of adolescents. This contextually informed perspective allows researchers to form links between national survey/statistical data and laboratory-based experimentation.

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## The Importance of Understanding Risk Taking in Adolescence

Risk taking in adolescence involves an understanding of the interaction between the youth's greater social environment, changing physiology, cognitive control abilities, and understanding of risk as it relates to his/her decision outcomes. Understanding risk taking in adolescence requires researchers to approach this question from a multilevel perspective (Cicchetti & Curtis, 2007). It requires that researchers consider how the changes occurring within the adolescent interact with the changes happening in the youth's social and academic environment (Bronfenbrenner, 1977). For example, there are biological changes occurring inside the teenager, such as an increase in gonadotropic hormones resulting in secondary sex characteristics (Sisk & Foster, 2004) and neural changes, such as synaptogenesis and myelination (Giedd, 2004). There are a variety of changes taking place outside of the teenager as well. Between puberty and adulthood, a child will potentially graduate from elementary school to junior high or middle school to high school. This change will impact their daily routine. It will impact how many teachers they have, how many new peers they meet, and the overall structure of their weekday. In addition to these shifting social demands, their transition from one grade level to the next also means an increase in academic demands, both inside and outside the classroom, in the form of afterschool assignments. There is also an increased expectation for autonomy, both from the teenager and from parents and teachers, and this transition into independence requires the teenager to rely less on the instruction of elders and more on her/himself. Each of these changes brings increasing complexity into the developing adolescent's experience and informs the field's understanding of adolescent risk taking

(Steinberg & Morris, 2001).

The increasing independence afforded to adolescents leads to concerns about reckless and potentially criminal behaviors that may put others in society at risk (Baumrind, 1987). In 1987, a paper was published in New Directions in Child Development calling for a developmental perspective on risk taking in adolescence (Baumrind, 1987). In response to a growing concern from the public regarding America's youth, Baumrind asserted that researchers must distinguish risk taking behaviors in adolescence from being at risk in adolescence, and to do that, adolescent behaviors must be regarded within the context of contemporary youth culture (Baumrind, 1987). It was a call for a contextualization of adolescence, which provided a wide age span for adolescence, ranging from ages ten to twenty-five, to allow for the myriad of physical changes potentially occurring during that time (Baumrind, 1987).

Some, particularly western cultures, view adolescence as a time when a teenager must separate her/himself from the family unit and take a different place in society (Belsky, Steinberg, & Draper, 1991). Although the degree and extent of separation from the family unit may vary, one indicator, the degree of disclosure to parents, decreases across both sexes and multiple cultures, including Latino, African-American, Hmong, and Dutch (Brown & Bakken, 2011; Keijsers, Branje, Frijns, Finkennauer, & Meeus, 2010). This indicates that adolescents may be questioning previously learned knowledge or trying to decide for oneself how risky an activity, peer or choice really is. This is relevant, because risk-taking behavior is an intricate component of being an adolescent and has the potential to facilitate healthy development, including a gain in self-confidence, stress tolerance, and taking initiative (Baumrind, 1987). It is important to

emphasize that while adolescents are overrepresented in morbidity and mortality measures, many youth also exhibit positive changes including the ability to navigate their increasingly complex environment (Dahl, 2011). While it is recognized that risk taking is an important concept for the developing adolescent, there is no doubt that risk taking also comes with less positive consequences (Arnett, 1992). Indeed, many researchers are concerned about the potentially harmful consequences of adolescence and focus their research on the negative outcomes of risk taking, such as sexual promiscuity, illicit drug use, and other delinquent behaviors. With this concern, it is important that researchers not neglect the potentially adaptive effects of risk taking in adolescence (Baumrind, 1987; Furby & Beyth-Marom, 1992; Steinberg, 2005). By viewing risk taking in adolescence as normative, it allows for the possibility of a more general understanding of risk taking across the lifespan, and the relationship between risk taking and other important processes that occur during adolescence.

Other scholars have noted the importance of having a developmental perspective on risk taking behaviors in adolescence (Arnett, 1992). Arnett noted that while adolescence is not necessarily a period of overwhelming storm and stress, adolescents are statistically overrepresented in every category of "reckless" behavior such as illegal drug use, minor criminal activity, sex without contraception, and reckless driving (Arnett, 1992). This observation remains accurate (Eaton et al., 2011). Indeed, placing an adolescent's decisions within a larger system may provide a clearer definition of normative risk taking and inform how risk taking may change from adaptive to maladaptive (Cicchetti & Curtis, 2007).

## Components of Risk Taking in Adolescence

Those who have argued that reckless behavior is especially prevalent in adolescence have sought explanatory mechanisms for why youth are overrepresented in risk outcomes (Arnett, 1992; Baumrind, 1987). This attempt lead to the suggestion that risk taking is integral to adolescent development (Arnett, 1992). Forms of reckless behavior that manifest in adolescence, such as driving at high speeds while drunk, or sex without contraception, are asserted to have underlying components unique to adolescence, namely sensation seeking and egocentrism (Arnett, 1992).

**Sensation Seeking**. Sensation seeking, "the need for varied, novel, and complex sensations and experiences and the willingness to take physical and social risks for the sake of such experiences" has been identified as one aspect of adolescent risk taking (Arnett, 1992; Zuckerman, Buchsbaum, & Murphy, 1980). An optimal level of excitement and stimulation is needed for organisms, including teenagers, to thrive (Zuckerman, Kolin, Price, & Zoob, 1964). A recent study examining sensation seeking in children, younger adolescents, and adults supports this assertion, and found that younger adolescents (12- to 15-year olds) reported greater sensation-seeking scores than either children (10- to 11-year olds) or adults (26- to 30-year olds; Steinberg, 2008).

**Egocentrism.** A second contributing factor to adolescent risk taking is adolescent egocentrism (Arnett, 1992; Elkind, 1967). The targeted health messages directed toward adolescents may often be ignored, because teenagers view themselves as an exception to the rule (Greene, Rubin, Hale, & Walters, 1996). For example, despite public health initiatives focused on decreasing texting while driving, 44% of drivers between 18 and 20 years old still report texting or emailing while driving (Tison, Chaudhary, & Cosgrove,

2011). This finding supports the argument that adolescents subscribe to a personal fable, and view themselves as personally immune to risk (Arnett, 1992; Elkind, 1967; Greene et al., 1996). This perspective helps explain why adolescents are statistically overrepresented in reckless behaviors and have the highest death rate for traffic related accidents (Miniño, 2010).

**Consequences of Sensation Seeking and Egocentrism.** Unfortunately, the relationship between a teenager's sensation seeking and subscription to a personal fable correlates with his/her perception of being at risk for AIDS or teenage pregnancy (Greene et al., 1996). In a study examining this relationship, items measuring one's personal fable included statements from three categories in which participants were told to rate each response by how much they agreed with each statement, from 1 (strongly disagree) to 5 (strongly agree): uniqueness, invulnerability, and omnipotence. A few sample statements, respectively, were "sometimes I think that no one understands me," "it is easy to take risks because I never get hurt," or "I believe that everything I do is important." Participants were also asked to rank how likely they would be to approach or avoid a risk. Their knowledge of AIDS, perceived susceptibility, and sexual behaviors were also assessed. Researchers found that a teenager's invulnerability measure was negatively correlated with healthy sexual behaviors (Greene et al., 1996). This indicates that although adolescents may be aware of a given risk, they may see themselves as invulnerable to it, and therefore less likely to take the necessary precautions.

Risk taking in adolescence can be either adaptive or maladaptive, and a clearer understanding of the underlying mechanisms involved in risk taking will improve the field's understanding of adolescence. This has consequences which not only impact the

risk-taking teenagers, but has implications for the surrounding community (Baumrind, 1986). It is only through a clear understanding of what contributes to a teenager's decision to engage in potentially risky activities that an effective approach can be used to alert teenagers to their lack of invulnerability and decrease undesirable outcomes.

**Separating Risk Taking From Reward Processing in Adolescence**

Risk taking behaviors in adolescence do not always come with concrete advantages and in some cases it is difficult to quantify the reward of such behaviors. Take for example, an adolescent who pierces her naval. The procedure is painful and during the typical school day it remains covered and hidden from other's view. Yet, the amount of care this type of piercing requires is extensive and the likelihood of infection is quite high. The acceptable environment to show such a piercing is in a swimming environment, but naval piercings are not to be submerged in water lest infection occur. Adolescence researchers have argued that peer approval is the driving factor in many adolescent activities (Arnett, 1992; Steinberg, 2008), but it is often the perceived peer approval and not the actual peer approval that the adolescent is seeking (Arnett, 1992; Elkind, 1967). Since it is perceived, but not necessarily actual, it may not be possible to quantify peer approval as a reward in the same way that one could quantify winning the lottery as a reward. When perceived peer approval is considered a tangible reward, the nebulous reward of piercing one's belly button is apparent: her peers will be impressed by this daring act of bravado.

A teenager's risk behavior does not always have a direct relationship to a reward, as illustrated by Arnett's example of a teenager driving at high speeds while drunk (Arnett, 1992). The risk involved in this behavior is apparent: the youth could be pulled over and

given a citation for speeding, or arrested for driving while intoxicated. He/she could also be involved in an accident and risk damaging the car or injuring oneself. Even worse, the youth could be responsible for crashing into and possibly killing another person. The reward in this case is not as apparent. At best the youth arrives to his/her destination safely, and while arriving safely would be a great gift, it is likely not the incentive for driving at high speeds while drunk. The incentive may be peer related, as peers are often present in the cases of drunk driving, but it is not clear if such behavior brings about greater peer acceptance (*Insurance Institute for Highway Safety*, 2011).

Sex without contraception is another form of reckless behavior that does not have a readily apparent reward (Arnett, 1992). The risk in this case could be teen pregnancy, and with the Center for Disease Control reporting that more than 400,000 teenage girls between the ages of 15- and 19-years old gave birth in 2009, it is still a significant public health concern ("Adolescent and School Health," 2009). In addition to teenage pregnancy, teenagers and young adults made up nearly half of the 19 million new cases of sexually transmitted diseases in 2009 ("Adolescent and School Health," 2009). In both of these cases, the reward for engaging in unprotected sex is not readily apparent. For females who do not use a condom, this behavior does not improve the sexual pleasure, but exposes her to a variety of contractible diseases or pregnancy (Catania, Coates, & Greenblatt, 1989; Raffaelli & Crockett, 2003). At most, the reward is not getting pregnant or not contracting an infection or disease, and in some cases, it may be the perceived approval by a partner that is a major component. As with the previous example, the number of times a pregnancy or an STD is avoided is not quantifiable, and the reward may go unnoticed by the adolescent because it is the absence of a harmful consequence

rather than a concrete reward. While risk can occur without reward, so too can reward occur without risk. In adolescence, this reward could be in the form of a scholarship, which is not typically associated with negative consequences. Rather, there are various benefits, such as esteem from parents, peers, and not least of all, a financial award.

The lack of observable rewards leads to difficulties in drawing basic assumptions about adolescent risk taking difficult. Drunk driving and unprotected sex represent two, potentially extreme, examples of aversive risk taking. The motivation underlying these behaviors is not readily apparent and requires a closer examination of what goes into this risk taking process.

**The Intersection of Risk Taking and Decision Making in Adolescence: Hot and cool executive function**

Noting the differences between adaptive and maladaptive behaviors during adolescence requires understanding how risk taking components, such as sensation seeking and self-perception interact and influence decision-making, especially decision-making regarding risk (Steinberg, 2005). Recognizing how adolescents are unique with regard to decision-making compared to adults will not only impact the types of questions researchers ask, but also inform how lawmakers treat adolescents in the legal system (Steinberg & Cauffman, 1996). While historically the legal system has viewed adolescents as less competent than adults, research has begun to show that from mid-adolescence on, they have many of the same cognitive skills and decision making abilities as adults (Steinberg & Cauffman, 1996). Yet, researchers and lawmakers are still perplexed by some of the decisions teenagers make. In the example of driving, researchers may not be able to measure each time a teenager drives recklessly, but

national statistics like those provided by the Highway Safety and Research Communications indicate that 16- to 19-year olds are at four times the risk for a crash compared to other age groups (2009). This is due in part to an adolescent's inexperience behind the wheel, as well as their tendency to speed (*Insurance Institute for Highway Safety*, 2011). Such a combination could be identified as risk-taking since the teenager is engaging in speeding, which increases his/her chances of a crash.

Adolescents engage in risk taking behaviors, but what motivates these behaviors is not always clear. An example in the previous section supported the argument that adolescents may see themselves as invulnerable (Greene et al., 2000). Risk taking involves choosing between alternative courses of action based on the assessment of how likely or unlikely it is that one will experience undesirable consequences, and teenagers may not view their actions as risky because they believe they are unique or invulnerable (Furby & Beyth-Marom, 1992). The adolescent may be overrepresented in risk outcomes because he/she does not see a risk and therefore does not make a choice to avoid the risk. Researchers must assess if teenagers are engaging in risky activities due to lack of cognitive control, or if teenagers have cognitive control and are weighing outcomes differently (Arnett, 1992; Furby & Beyth-Marom, 1992; L. Steinberg, 2008).
This understanding requires a clear picture of the cognitive control abilities of the adolescent. To assess the likelihood that the adolescent is considering outcomes differently requires an evaluation of an adolescent's cognitive capacity (the conscious control of one's thoughts, actions, and emotions), and is typically assessed through varying measures of executive function (Lamm, Zelazo, & Lewis, 2006). This perspective requires understanding the bidirectional feedback mechanisms involving

different components relevant to adolescence development (Gottlieb, 1998). Approaching adolescent risk taking from a multilevel perspective that examines the teenager's behavior both from the social and emotional perspective of hot executive function and the more detached cognitive perspective of cool executive function will better equip researchers to study this dynamic period of human development.

**The development of cool and hot executive function in adolescence.** Understanding why teenagers approach risk taking differently than both children and adults requires knowledge of how they come to make decisions. If, for example, they rely on a similar set of cognitive mechanisms as adults, but attend to different components in their environment, then researchers would need to approach questions regarding teenagers and their risk taking behaviors from a different angle than they would for an at-risk adult population. Rather than informing teenagers of dangerous risks and expecting them to make similar inferences and decisions as an adult would, it may be beneficial for parents, teachers, and health officials to appeal to elements relevant to the adolescent, such as peer opinion (Baumrind, 1987; Greene et al., 1996; Prinstein, Boergers, & Spirito, 2001). However, if teenagers are in an earlier state of cognitive development compared to adults, then one could infer they are engaging in risk behaviors because they lack the necessary cognitive functions to accurately identify and deal with risk. A scaffolding approach could be used to assist the teenager with mastering these cognitive functions (Vygotsky, 1986).

***Cool executive function in adolescence***. There is an assertion by some that adolescents consider both the cost and benefits associated with a specific action and thereby engage in similar decision making processes as adults (Reyna & Farley, 2006;

Steinberg, 2008). This definition is similar to our field's current construct of executive function (EF), including aspects of inhibition, and shifting (Best & Miller, 2010). To better understand whether teenagers approach risk differently, one should first consider any developmental differences in inhibitory control and cognitive flexibility. Simple-response inhibition is most relevant in the early stages of development when a child must learn to refrain from something, like eating a treat (Mischel, Ebbesen, & Zeiss, 1972). Most inhibitory tasks used in childhood, adolescence, and adulthood tap into inhibition in the context of a complex cognitive task. In childhood these tasks include the day-night task, Luria's hand game, and the Dimensional Change Card Sort (Carlson & Moses, 2001; Zelazo, Müller, & Frye, 2003). More appropriate tasks for adolescents and adults include the Go-No-Go task, the anti-saccade task, the Eriksen Flankers task (ANT), the Set-Shifting task, the NIH Toolbox version of the Dimensional Change Card Sort, and the Stroop-like task (Casey, Trainor, & Orendi, 1997; Huizinga, Dolan, & van der Molen, 2006; Lamm et al., 2006; Liston, Matalon, Hare, Davidson, & Casey, 2006; Luna & Sweeney, 2004).

There are marked improvements in inhibition from early childhood to early adulthood. Most inhibitory control tasks, like the Go No-Go task, have illustrated that complex-response inhibition continues to improve through adolescence (Berg & Byrd, 2002; Best & Miller, 2010; Casey et al., 1997); and with the Stroop-like task, improvements continue until age 21 (Huizinga et al., 2006). This lengthened period of development indicates that even if an adolescent uses reasoning in an adult-manner, he/she may still have difficulty refraining from an action if the cognitive load is great enough. This may be true even if the goal would be facilitated by inhibiting one's

behavior.

Consider for a moment a 15-year-old with a driver's permit who is behind the wheel on a busy avenue. As she is driving she approaches a yellow traffic light. The moment she sees the light she must shift her response from one that is dominant to one that is less practiced—that is, her foot must shift from the acceleration pedal to the brake pedal (considering that much of one's driving time is spent with one's foot on the acceleration pedal rather than the brake pedal it can be argued that this is a more practiced behavior). Since complex-response inhibition is still developing she may have difficulty with this task. Even if she intends to stop right away, she may take a few milliseconds longer than intended. Although simple inhibition is mastered, complex inhibition is still developing and reflects Diamond's theory on attentional inertia (Kirkham, Cruess, & Diamond, 2003). At this stage, it is the coordination of multiple processes, seeing the yellow light, determining the amount of time before the light turns red, choosing to stop, switching from the accelerator to the brake, stopping behind the white line, rather than a single action, that must be mastered.

Shifting (e.g., cognitive flexibility), the ability to switch between mental states, rule sets, or tasks improves with age (Friedman et al., 2006; Miyake et al., 2000). Adolescents reach adult levels of accuracy by 15 years of age (Huizinga et al., 2006). There are various versions of set shifting tasks used in the literature, all of which involve a component in which the participant must ignore one response set in favor of another (Best & Miller, 2010; Liston et al., 2006). While accuracy measures of cognitive flexibility remain relatively stable after age 15, reaction times follow a different developmental trajectory with improvements occurring into adulthood (Davidson, Amso,

Anderson, & Diamond, 2006). Some interpret this as an indicator that adolescents are improving in their ability to reflect on their behavior and adapt, or slow down when they notice an increase in errors (Best & Miller, 2010).

This ability is particularly relevant when considering the number of contradictory messages an adolescent may receive and have to act on. On a given day, a teenager may read a blog boasting about the benefits of social drinking, hear admonitions from a parent about alcohol use, see a billboard warning about the dangers of binge drinking, and then have a close friend ask him to go to a party where alcohol is present. In the face of the different statements about alcohol, the teenager must decide whether he will attend the party and drink, attend the party and not drink, or avoid the party altogether.

In summary, inhibition is an important construct that changes over the course of development, and continues to marginally improve into adulthood (Berg & Byrd, 2002; Huizenga, Crone, & Jansen, 2007; Munoz, Broughton, Goldring, & Armstrong, 1998). And cognitive flexibility skills in adolescence reach adult levels of accuracy by age 15 (Huizinga et al., 2006). While both of these components of EF are approaching adult levels, they are not entirely at capacity and this may contribute to challenges adolescents face in decision making.

***Hot executive function in adolescence.*** Understanding a teenager's ability to accurately gauge the riskiness of a situation is an important step for identifying why teenagers engage in a greater number of risk behaviors compared to adults. Researchers have established that once a teenager has a set of premises on which to make a decision, the cognitive control skills for acting on that decision are quite advanced, but are still developing (Best & Miller, 2010). A working paper for the Carnegie Council on

Adolescent Development (Furby & Beyth-Marom, 1992) examined adolescent risk taking from a decision-making perspective and found that while general cognitive processes were not impaired, emotional and peer influences had a greater impact on adolescent behavior as a whole. Not only are the underlying cognitive and biological underpinnings still developing through adolescence, it is likely the adolescent may be responding more to emotional or social factors in the environment.

In a review of reckless behavior in adolescence, Arnett (1992) summarized two common heuristics described by Kahneman and Tversky (1972; 1973) and tailored them to how teens may use them for judging probability. The first is representativeness, or how similar the sample descriptive matches the population descriptive (Kahneman & Tversky, 1972). Although two occurrences may both be equally likely, a person may favor one that closely matches their archetypical example. For example, before a teenager decides whether or not to skip class, he may assess how many students typically skip class and get away with it. His school administration may pay strict attention to the amount of absences (the parent population), and have a strict attendance policy, but he is a student athlete (the sample population) and believes that the likelihood of getting caught is slightly lower for athletes, than it is for students generally. Student athletes are as likely to get caught as other groups, which this male athlete is aware of, however, he is more likely to disregard the knowledge of this probability due to another heuristic.

The second component of assessing probability is the availability heuristic (Tversky & Kahneman, 1973), or how quickly relevant instances come to mind. Arnett describes this as how likely it is that a teenager thinks she will “get away with it” (Arnett, 1992). In the case of adolescents, “it” could be a number of things from speeding to skipping class. If

the male athlete knows the school has a strict attendance policy, but can only think of non-athletes who have gotten caught, he may assume he will not get caught. He may also assume, that the probability of getting caught does not apply to him, because he is unique. Arnett's assertion that teenagers are more likely to disregard the representativeness heuristic and favor the availability heuristic shows that while adolescents may be aware of risk, they are able to quickly disregard this knowledge when they have readily available and contradicting examples (Arnett, 1992). Being able to quickly identify several scenarios in which friends have engaged in drinking behaviors without getting caught, and not being able to identify friends who have gotten caught may likely provide the teenager with the impression that she will also get away with drinking alcohol. In these examples, it appears that even when a teenager is aware of the associated negative outcomes of a decision, she may assume that those outcomes do not apply to her. Indeed, findings from the National Youth Risk Behavior Survey (Eaton et al., 2011) examining 9th – 12th graders of representative public and private schools in the 50 states show that 72.5% of teenagers drank alcohol on at least one day during their lives and 24.2% of teenagers had at least five drinks in a row in a given instance of drinking. Since the drinking age in the United States is 21-years-old, drinking in high school puts a teenager at risk for an underage drinking citation at any time. While other variables, such as parental attitude about underage drinking may vary, the legal drinking age does not and there is always the possibility of getting caught. In addition to drinking behaviors, according to the NYRBS, 46.3% of teenagers have tried smoking at least once. This is telling when one considers the sheer number of anti-smoking advertisements that currently exist in our society (Cohen, Shumate, & Gold, 2007). These advertisements

feature extreme consequences of smoking and some appeal to the importance of peer influence by highlighting how uncool one looks when smoking. This implies that teenagers may still engage in risky behavior even when the risk is apparent, because they do not think the probability of risk applies directly to them.

Adolescent development is marked by an increase in sensitivity to peers, and a decrease in the quality of interactions with parents as indicated by the increase in "bickering and squabbling" (Steinberg & Morris, 2001). It is likely that the teenager's decision making is due largely to an additional set of values she has developed based on perceived peer opinion. From the classroom to the after-school hangout spot, teenagers spend a large amount of time around peers. Potentially, this presents an increased probability that the adolescent will be faced with decisions involving some amount of risk. The risk could be relatively small, like skateboarding, or the risk could be larger, like skateboarding without a helmet. Either way the teenager must decide whether he/she will engage in an activity based on either his/her current knowledge (e.g., that his/her friends are doing it), or on his/her previously learned knowledge (e.g., that his/her parents think it is dangerous). Even if an adolescent makes the logical decision not to engage in an activity, she may have difficulty following through if her bottom-up fear of social disapproval overrides her top-down executive response.

The number of teenagers who still try alcohol or cigarettes at least once supports the idea that teenagers may see the probability of a negative event happening to them as only weakly representative (Elkind, 1967; Arnett, 1992). This suggests that their basic reasoning skills are not hindered, rather teenagers think the odds do not apply to them. This personal fable can lead to a sense of invincibility (Elkind, 1967). In the situation of

underage drinking, a youth may assume that although someone else may get a citation for underage drinking, she is not someone else, she is unique, and therefore the possibility of being cited does not apply to her.

**Considering Biology in Adolescent Risk Taking and Decision Making**

Understanding risk taking in adolescence requires insight into the underlying constructs involved in cognitive control, such as shifting, and inhibition. Although there are some behavioral changes, the simple forms of these components are developed in childhood (Best & Miller, 2010). However, as the cognitive demands increase in complexity, the developmental differences also increase (Huizinga et al., 2006). Many of the cognitive demands in an adolescent's life are increasingly adult like, such as driving, working, and social bonding, yet their behavioral responses have yet to reach adult levels. In order to better understand why these differences exist, one must also consider the existence of biological differences.

As the unique biological profile of adolescence is discussed, it is important not to assume a one-to-one relationship between cognitive development and biological development, especially neuronal development. Although differences have been observed, there is a long way to go before the implications of these biological differences are fully understood. While interpretation can be difficult, it is still important for researchers to acknowledge the major biological differences between children, adolescents, and adults. For example, secondary sex characteristics due to gonadal steroid hormones and sexual behaviors come online at this time (Cameron, 2004: Catania et al., 1989); although adolescent sexuality is developing, the initiation of sexual behavior still depends on what is normal for one's peer group (Brooks-Gunn & Furstenberg, 1989).

This implies that decisions about sex are not solely dependent on biological input, but rather they rely on a complex interaction between the changes taking place with the adolescent's physiology and the adolescent's social group.

In an ongoing longitudinal pediatric brain MRI study currently being conducted at the National Institute of Mental Health, changes in cortical gray matter and white matter have been observed in a cohort of 161 healthy youth (Giedd, 2004). Cortical gray matter follows an inverted U-shaped pattern through development: frontal gray matter volume peaks at about 11-12 years of age, and temporal gray matter volume peaks at about 16 years of age. The leveling off of frontal gray matter volume in early adolescence suggests a stabilization and tapering off of neuronal connections and may help explain why performance on simple cognitive tasks are developmentally mature. While the temporal gray matter volume does not peak until mid-adolescence, this prolonged neurological development parallels what is happening behaviorally with social interactions. As was mentioned in the introduction, adolescents engage in egocentric thinking and this may be attributed to the protracted development of social cognition (Elkind, 1967). A lack of social awareness is also found in individuals on the autism spectrum (Zilbovicius et al., 2006). In these individuals, there appears to be a decrease in gray matter within the superior temporal sulcus relative to other groups (Zilbovicious et al., 2006). The superior temporal sulcus has been indicated more generally in one person's ability to predict another's behavior (Pelphrey, Morris, & McCarthy, 2004).

Unlike the inverted U-shape of cortical gray matter development, white matter development follows a more linear pattern and continues across adolescence and into adulthood (Giedd, 2004). Since myelination occurs after neuronal connections are

established, it is used as one indication of neurological maturation (Giedd, 2004). The wrapping of the fatty sheath around neuronal axons can increase the signal between neurons up to 100 times that of an unmyelinated axon (Giedd, 2004); and this may theoretically improve one's engagement in cognitively complex tasks such as shifting between demands in daily life. In addition to Giedd's longitudinal study, a postmortem study of 164 normal individuals ranging from infancy to 76 years of age showed particularly active development of white matter connections between the frontal cortex and hippocampus during adolescence (Benes, Turtle, Khan, & Farol, 1994). This is relevant because efficient cognitive control requires the automaticity of lower level processes and a tightening of networks involving the dorsolateral prefrontal cortex (DLPFC) and the hippocampus (Paz-Alonso, Bunge, Anderson, & Ghetti, 2013). This finding implies that adolescent performance on cognitive tasks may be qualitatively different from children and adults because the functional connectivity between the dlPFC and the hippocampus coming online during adolescence (Benes et al., 1994).

Functional brain differences have also been reported between adolescents and adults. A lesion study by Bechara and colleagues (1994) demonstrated that the ventromedial prefrontal cortex (vmPFC) was the most critical brain area for successful performance on the Iowa Gambling Task (IGT) in adults. Since 1994 these findings have been supported by others (Hooper, Luciana, Conklin, & Yarger, 2004);the IGT is a prototypical task examining risk and reward processes; the task requires individuals to choose between four decks of cards with varying levels of reward and punishment. For individuals to maximize points they must choose the decks that are advantageous in the long run (modest reward, but low punishment) and avoid the decks that are advantageous

in the short run, but disadvantageous overall (high reward, but high punishment) (Bechara, Damasio, Damasio, & Anderson, 1994). Importantly, successful performance on this task requires inhibition, working memory, and shifting abilities, which may be dependent, in part, on the development of the vmPFC (Bechara et al., 1994; Hooper et al., 2004).

Hooper and colleagues (2004) were interested in developmental differences between individuals in early adolescence and those in later adolescence based on performance on the IGT. Their results showed that older teenagers switched to advantageous decks more quickly, and since behavioral performance is correlated with activation of the vmPFC, they concluded that maturation of vmPFC was occurring across adolescence (Hooper, Luciana, Conklin, & Yarger, 2004). Because performance on the IGT requires inhibition, working memory, and shifting abilities, and also relies on activation in the vmPFC, this indicates the vmPFC may be important for cognitive control in the presence of risk and should mature as the teenager develops.

Teenagers may engage in risk taking behaviors because of competition between the prefrontal (top-down) processes and subcortical limbic (bottom-up) processes (Casey, Getz, & Galvan, 2008). This competition is thought to be present because of the discrepancy in maturation between the prefrontal cortex (PFC) and the limbic system (e.g., the nucleus accumbens and amygdala; Casey, Jones, & Hare, 2008). In corroboration, a Diffusion Tensor Imaging (DTI) study of white matter maturation in 114 individuals between the ages of 8 and 28 found that prefrontal-striatal connections had not yet matured in the adolescents between ages 13 and 17 (Asato, Terwilliger, Woo, & Luna, 2010). Referred to as the Dual Systems Hypothesis, this discrepancy between

systems is thought to account for the curvilinear pattern of increased reward seeking and impulsivity during adolescence, which is marked by increases during the beginning and middle stages of adolescence and decreases during later adolescence, at the same time top-down processes, like self-control, come online (Steinberg, 2010). Indeed, researchers examining adolescent rodents found that the nucleus accumbens develops early relative to the orbitofrontal cortex (Laviola, Macrì, Morley-Fletcher, & Adriani, 2003), and in humans there is a positive relationship between activation in the nucleus accumbens and the likelihood of engaging in risk behavior across development (Galvan, Hare, Voss, Glover, & Casey, 2007). The late maturation of amygdalo-cortical connectivity in rodents suggests that there is an imbalance between systems of emotion and reason during adolescence (Cunningham, Bhattacharyya, & Benes, 2002). If such is the case for humans, then adolescents may not yet have the regulatory capacities important for monitoring emotional states and regulating emotional responses.

An emotional go-no-go task in the MRI environment was administered to children, adolescents, and adults to examine potential differences in limbic activation in response to emotional stimuli (Hare et al., 2008). The participants were presented with a series of pictures showing emotional faces and told to press for one of the facial expressions and refrain from pressing for the other facial expressions. While adolescents and adults responded significantly faster than children, adolescents showed wider variability of activation patterns in the amygdala with a greater amount of signal change (Hare et al., 2008). Hare and colleagues identified this as support for the lack of top-down control systems and the presence of bottom-up processes in adolescents. This study provided insight into the role that emotion plays in inhibitory control, and showed that while

adolescents can inhibit, they have greater variability in bottom-up activity compared to adults. This variability may support the Dual Systems Hypothesis, but recent work has brought this assumption into question by positing that while adolescents do not exhibit adult-like, top-down processes, they may exhibit compensatory activation of the ventral striatum (VS) which stills allows for regulation of bottom-up processes (Pfeifer et al., 2011). Indeed, Pfeifer and colleagues (2011) have argued that regulatory processes of the vmPFC may be aided by the subcortical VS, which may either be compensating or enhancing roles typically thought to be carried out by the vmPFC. While patterns between adolescents and adults may be different, this finding suggests caution in assuming that adolescents do not have other ways to regulate their responses.

Emotion processing is important to adolescent development in its own right, but it may also inform one's perspective on cognitive control. The presence of emotional stimuli could potentially shift the cognitive process from one of cold cognition to one of hot cognition, or at the very least, could increase the level of regulation needed to successfully complete the task. For example, another study used the emotional oddball task to examine the connection between neuronal activation and emotional content (Wang, Huettel, & De Bellis, 2008). Adolescent participants between the ages of 10 and 15 were presented with a series of images (e.g., sad or neutral pictures) in the fMRI environment (Wang, Huettel, & DeBellis, 2008). Compared to adults, adolescents showed additional recruitment of the right vmPFC when a target stimuli was followed by a sad image (Wang, Huettel, & DeBellis, 2008). This task provides evidence that teenagers do not exhibit the same pattern of neurological results to emotional stimuli compared to adults. While making meaningful inferences are difficult, this study does

provide an additional layer of support for the assumption that adolescents may not approach or interpret emotional cues in the same way as adults. Pfeifer and colleagues (2011) suggest that during early adolescence, youth may depend on VS activation to regulate responses to interpersonal information (via emotional faces), and this may account for the differences observed between adolescents and adults.

It is also likely that the engagement of adolescent cognitive control systems are not simply the consequence of two systems coming to equilibrium, with the top-down, prefrontal cortex continuing to mature as the development of the bottom-up, nucleus accumbens and ventral striatum taper off. Rather, context may play a role in which systems are recruited in a given situation. Indeed, after a review of the adolescent brain literature, Crone and Dahl (2012) have proposed the consideration of a third model that accounts for the increasing importance of emotion and peers during adolescence. They argue that not only are regions important for cognitive control coming online during adolescence, but so too are regions important for social cognition (Crone & Dahl, 2012). This would include such regions as the medial prefrontal cortex, the temporal-parietal junction, the subgenual anterior cingulate cortex, and the insula (Crone & Dahl, 2012). The recognition of these regions in current models could help account for the adolescent's increasing concern for peer approval, since the maturation of these areas help account for improved perspective taking and theory of mind development, and they could help account for the motivational salience that peers offer in a variety of contexts, including classroom and after-school activities (Crone & Dahl, 2012).

With the increase of gonadotropic hormones, the stabilization and tapering off of neuronal connections in gray matter, and the increase in white matter pathways between

prefrontal and subcortical regions, there are a myriad of changes occurring at the biological level during adolescence which makes this period of decision making unique (Asato et al., 2010; Cameron, 2004; Giedd, 2004). In addition, the myelination and structural connectivity between the vmPFC and hippocampus, as well as the differential activation of prefrontal regions relative to nucleus accumbens and amygdala in adolescents compared to adults, and the functional regulation of VS and amygdala in young adolescents, as well as the gradual development of the medial prefrontal cortex and other areas related to the social brain, all provide evidence that important neurological changes are occurring during this period (Casey, Jones, & Hare, 2008; Crone & Dahl, 2012; Galvan et al., 2006, 2007; Hare, Tottenham, & Galvan, 2008; Hooper et al., 2004; Pfeifer et al., 2011). These changes may contribute additional complexity to the adolescent's decision-making as he/she engages in cognitive processes involving potential risk.

**Conclusion**

The variety of changes occurring across multiple levels of development during adolescence indicates this as a period of vulnerability (Casey et al., 2008; Huizinga et al., 2006; Steinberg, 2005; Steinberg et al., 2008). Indeed, teenagers engage in greater amounts of risk taking compared to children and adults (Arnett, 1992). Many of these developmental differences are reflected in the adolescent's changing biology. While researchers must be cautious with assuming any one-to-one relationship between any biological factor and behavioral factor, knowledge of biological components does allow researchers to place adolescent cognition within a larger developmental framework. There are increased cognitive demands during adolescence, in both the scholastic and

social environments. And adolescents perceive greater value in the approval and acceptance of their peers. These factors all may play a role in the adolescent's increased engagement in risky behaviors.

While the outward physical changes are apparent to the adolescent, there are also changes in cortical gray matter and white matter (Giedd, 2004). In the midst of these physical changes, adolescents are engaging in complex heuristics when making decisions. Teenagers must not only engage in shifting, and inhibiting processes in the laboratory; these skills must also be called upon daily when making decisions in hot environments, such as those found in the presence of peers. The adolescent must assess the representativeness of a decision, or the likelihood of a decision outcome applying to them (Arnett, 1992). This requires the adolescent to consider the odds involved with different choices and to act accordingly. In addition to assessing the representativeness of a decision, teenagers must also access examples of these decision outcomes as they apply to people they know (Arnett, 1992). Not only must an adolescent engage in this complex process to reach a decision, but he/she must also act on this decision. These cognitive and biological changes are occurring while the adolescent has yet to understand that others are not always focused on his/her actions (Elkind, 1967).

Either because of or in line with these physical and cognitive changes, the adolescent is quite sensitive to peer influence. Not all teenagers may engage in dangerous activities during adolescence, but for those that do, it is important to understand how many of those decisions are motivated by their desire to gain perceived peer acceptance (Baumrind, 1987; Crone & Dahl, 2012; Prinstein et al., 2001). The understanding that there are different goals for adolescents compared to adults may help to explain the

discrepancies in cognitive processes of adolescents, and this will inform not only research, but public policy and court proceedings. Before a clear distinction can be drawn between an adolescent's decision making abilities and an adolescent's choice to engage in risk, we must first understand if factors unique to the adolescent environment, such as peers, influence their executive function abilities, such as inhibitory control, and cognitive flexibility (Best & Miller, 2010; Crone & Dahl, 2012). Previous research has supported the premise that while general cognitive skills are only marginally impaired in adolescents when compared to adults, peers may exert a greater level of influence during adolescence compared to both childhood and adulthood (Crone & Dahl, 2012; Furby & Beyth-Marom, 1992; Gardner & Steinberg, 2005). However, the role of peer influence on cool executive function abilities has not been directly examined.

In summary, understanding the biological and cognitive changes taking place in adolescence only provides a piece of the picture of why teenagers are increasingly engaging in risk taking behaviors compared to children and adults. A fuller understanding of why adolescence is a period of vulnerability requires considering how these biological and cognitive changes are influenced by peers. Rather than looking at smaller pieces of a whole, the field stands to benefit from putting the pieces together and recognizing the adolescent as a dynamic organism and adolescent cognitive control as a complex process. Integrating standard measures of adolescent cognition with an ecologically relevant component, such as peer presence, will help create a clearer picture of why risk taking in adolescence occurs and whether manipulation of the external environment can shift adolescent behavior.

# Chapter Two: An Introduction to the Current Study

## Contextualizing Cognition: Adolescent Risk Taking and Decision Making

It is important to consider how performance on cognitive tasks may be applied outside of the laboratory. Approaching adolescent risk taking and decision making from an ecologically valid perspective allows researchers to form links between national survey data and laboratory data. Unlike construct-specific laboratory procedures, adolescents must engage in a constant variety of challenges that require them to rely on a combination of EF skills at any given moment. Take for example an adolescent attending a driver's education course. To successfully complete the course, the student must accurately hold the driving instructions in mind and maneuver the vehicle appropriately: this requires working memory (Miyake et al., 2000). The student must also shift between instructions she mastered the session before and focus on the new set of instructions: this requires that she shift between instruction sets (Liston, Matalon, Hare, Davidson, & Casey, 2006). If the student is encouraged by her peer to go faster than the recommended speed, then she may need to inhibit her desire for peer approval to successfully follow instructions and pass the course (Miyake et al., 2000). How the adolescent responds to the last element of this example is contingent on both the perceived risk of speeding and the potential for peer disapproval.

Adolescents, more than children and adults, are quite sensitive to peer influence (Prinstein, Boergers, & Sprito, 2001; Steinberg, 2008). This sensitivity to their peers

coupled with adolescent egocentrism may inform how teenagers approach situations involving risk taking and decision making. In a situation where the teenager feels he/she must engage in a risky behavior for peer approval, the fear of rejection may result in the teenager engaging in a sub-cortical bottom up fear response that overrides the top down processes of cognitive control, akin to the Dual Systems Hypothesis (Casey et al., 2008; Steinberg, 2010) In the example above, the adolescent has the ability to engage in complex cognitive tasks, but the presence of peers may shift her goals from successfully completing the lesson to impressing her peer. This potential shift from one goal to another adds another level of complexity in understanding adolescent decision making and risk taking.

Additionally, the greater the environmental complexity, such as demands present in hot EF conditions, the more cognitively challenging a situation is for the adolescent. This is relevant because the cognitive complexity of a decision may be influenced by the adolescent's environment, such as the presence of peers (Prinstein, Boergers, & Sprito, 2001; Steinberg, 2008). While basic EF abilities reach adult levels by mid-adolescence (Best & Miller, 2010), when the cognitive demands increase, there is a decrease in adolescent performance compared to adults (Prinstein, Boergers, & Sprito; 2001; Steinberg, 2008). The previously discussed measures of EF, such as the Eriksen Flanker Task, represent cool cognitive tasks that do not take contextual demands, like peer influence, into consideration (Luciana & Nelson, 1998; Munoz et al., 1998; Prencipe et al., 2011). This makes it difficult to decipher how an adolescent's performance may vary

as a function of peer influence versus other components that contribute to task complexity. Considering peer presence as an ecological factor in risk taking and decision making could account for some of the performance variance seen in adolescence. Indeed recent work in adolescent development has begun the process of unraveling the role of peers in risk taking measures. The Stoplight Test (also referred to as the Chicken Task), is a measure of risk taking that uses a first-person driving paradigm (Gardner & Steinberg, 2005; Mather, Gorlick, & Lighthall, 2009). Participants view their car on the bottom of the screen along with a traffic light, and they are instructed to gain as many points as possible by driving their car as far as possible. As they are driving, the traffic light turns from green to yellow, at which time they must decide how much further they are willing to drive their car, with the understanding that if they have not stopped when the traffic light turns red, then they will be "pulled over by the police" and lose all their points for that round. This task was administered to participants from three age groups: (1) adolescents (13- to 16-years old); (2) youths (18- to 22-years old); and (3) adults (over 24-years old). Half of the participants completed the task in the presence of two same-aged peers and half completed the task on their own. Both adolescents and youth took significantly greater risks than adults when in the context of their peers (Gardner & Steinberg, 2005).

The Balloon Analogue Risk Task (BART) is another risk task which has recently been examined in the peer context (Cavalca et al., 2013). Risk taking on the BART (e.g., number of pumps) is strongly correlated to adolescent substance use, sexual behavior,

and delinquency (Lejuez et al., 2007). To examine the role of peer influence on risk taking, adolescent smokers and non-smokers completed the standard version of the BART and a computer simulated, peer version of the BART in counterbalanced order (Cavalca et al., 2013). The peer version of the BART was identical to the standard version of the BART except for two changes. Participants were told that: (1) an interactive BART had been created, which teenagers logged onto through a Google page, and (2) they would be observed by another participant who was familiar with the task and who would make suggestions in a chat box (Cavalca et al., 2013). Adolescent smokers engaged in greater risk taking in the peer version of the BART compared to adolescent non-smokers (Cavalca et al., 2013).

The increased level of adolescent risk taking in both the Stoplight Test and the BART when participants were in the presence of their peers (real or virtual), supports the consideration of ecologically valid measures, such as peer influence, when examining adolescent risk taking and decision making. Several studies have examined the role of peer influence on risk taking measures (Cavalca et al., 2013; Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005; O'Brien, Albert, Chein, & Steinberg, 2011), yet no studies have measured the influence of peers on adolescent decision making. It may be that tasks that measure the possible role of peers on multiple components of EF, in both hot and cool contexts, would provide an ecologically valid measure of adolescent risk taking and decision making.

Previous models have predicted an inverse u-shaped curve in relation to

motivation/arousal and performance (Yerkes & Dodson, 1908). A possible function of peer presence may be that of motivation or arousal, with peer presence representing a reward in cool EF contexts or additional arousal in hot EF contexts. Considering the relation between peer presence and performance in relation to an inverse U-shaped curve provides a model that allows for predicting how peer presence may influence both cool and hot EF performance.

**Hypotheses**

The current study investigated the effect of peer presence on decision making, including two measures of cool EF (the Dimensional Change Card Sort Test and the Attention Network Test) and two measures of hot EF (the BART and the Stoplight Test) in a sample of younger adolescents (12-15 year olds) and older adolescents (18-21 year olds). The main hypotheses of this study were designed to test whether peer presence served as a distractor (i.e., decreased EF performance in peer context) or a motivator (i.e., increased EF performance in peer context) in cool and hot decision making processes, and to replicate previous findings on adolescent risk taking.

When considering the role of peers as motivating, cool and hot EF measures may follow an inverted U-shaped curve of performance and arousal (see Figure 1). On cool EF tasks, (i.e., EF tasks without the presence of an explicit reward such as points earned) the absence of external motivation, such as peers, may lead to little motivation/arousal and consequently poor performance. In contrast, a cool EF task in the presence of peers may increase motivation/arousal and therefore performance. Because hot EF tasks may

already provide motivation/arousal, then performance on a cool measure of EF with peers present may be similar to a hot measure of EF with peers absent, and hot EF performance without peers may be optimal. This assumes that a hot EF task and the presence of additional motivation/arousal may decrease performance.

[Insert Figure 1 about here.]

If the relationship between performance and motivation/arousal follows an inverted U-shape, then following would be supported: (1) both younger and older adolescents would perform significantly better on cool EF measures when peers are present versus absent; (2) both younger and older adolescents would perform significantly better on hot EF measures when are absent versus present; Based on previous research, it was predicted that: (3) both younger and older male adolescents would take significantly more risks on the hot EF tasks in both contexts compared to younger and older female adolescents.

# Chapter 3: Methods

## Participants

Participants were younger (12-15 yrs) and older (18-21 yrs) male and female adolescents. Due to technological errors, not all participants' data were recorded on all four tasks (See Table 1). The following participants were included in this study's analyses: for the DCCS there were 50 younger adolescents (21 females) and 55 older adolescents (31 females); for the ANT there were 43 younger adolescents (19 females) and 55 older adolescents (33 females); for the BART there were 38 younger adolescents (18 females) and 45 older adolescents (26 females); for the STOP there were 20 younger adolescents (10 females) and 42 older adolescents (26 females). Younger adolescents were recruited through participating middle schools and a subset were recruited through the Institute of Child Development's Infant Participant Pool. Older adolescents were recruited through the University of Minnesota. For additional details on recruitment methods see Appendix A.

**Younger adolescents (YA).** A total of 21 females and 29 males between 12 and 15 year olds (M = 12.96, SD = +/- .74) were included in this study (See Table 2.1 for additional demographic details). While data was collected on 99 younger adolescents, many were excluded due to the lack of two, same-sex peers. Of the 50 participants, 44 identified as White, two identified as American Indian, two identified as Hispanic, one identified as Black, and one identified as "Other." All but one participant reported

English as their primary language.

[Enter Table 2.1 About Here]

**Older adolescents (OA).** A total of 31 females and 24 males between 18 and 21 year olds (M = 19.27, SD = 1.12) were included in this study (See Table 2.2 for additional demographic details). Similar to YA, sample sizes for each study will vary slightly due to the nature of peer testing (see Table 1). Of the 55 participants, 40 identified as White, 11 identified as Asian, three identified as Hispanic, and one identified as “Other”. Seven participants did not indicate a race. English was the primary language of 47 participants.

[Enter Table 2.2 About Here]

**Experimental Condition**

A within subjects design was used to test performance differences in cool and hot executive function. All participants completed the behavioral tasks in two contexts: an

alone context and a peer context. According to the Peer Relation Survey, of the 50 YA, 22 were identified as strangers, 9 were identified as acquaintances, and 19 were identified as friends. With the 55 OA participants, 43 peers were identified as strangers, 4 as acquaintances, and 2 as friends (six participants failed to complete a peer relation survey). Each testing group was randomly assigned to complete the computer tests in the alone or peer context first. In both the alone context (See Figure 2a) and peer context (See Figure 2b), the order of tasks for each participant was randomly chosen from one of four orders (i.e., ABCD, BCDA, CDAB, DABC). Therefore, task order varied for individuals within the same peer group.

**General procedure**. Participants were seated in front of a computer monitor where they completed two cool executive function and two hot executive function (i.e., risk and reward) tasks. The cool executive function tasks consisted of the Dimensional Change Card Sort Test (DCCS; NIH-Toolbox, Weintraub et al., 2013) and the Flanker Inhibitory Control and Attention Test (ANT; NIH-Toolbox, Weintraub et al., 2013). The hot executive function tasks included the Stoplight Test (STOP; Mather, Gorlick, & Lighthall, 2009) and the Balloon Analogue Risk Task (BART; Lejuez, Aklin, Zvolensky, & Pedulla, 2003). Participants also completed a series of questionnaires. The four behavioral tests and questionnaires are described in additional detail in the measures section.

***Alone context***. During the alone context, groups were instructed to keep their eyes on their own screen and not speak to anyone. Due to the nature of group testing and

limitations of available technology, it was necessary for all participant groups to complete the tasks in the same computer lab. While participants completed the tests, the experimenter(s) walked around the room and, if necessary, reminded participants to look at their own screens.

[Enter Figure 2a About Here]

***Peer Context.*** At each group testing session, consent forms were divided based on gender and order of receipt. Participants were then assigned as Peer 1, Peer 2, or Peer 3 in a group of three based on gender, and order of receipt. Each of the three peers completed all four tests and also watched as the remaining two peers completed the tests. Peer 1 completed the four tests in random order first, and then watched Peer 2 and Peer 3 complete these same four tests, each in random order. Following Gardner and Steinberg's (2005) design regarding peer interaction, no explicit instructions were given to participants regarding what to say in the peer observation context.

[Enter Figure 2b About Here]

## Measures

**Cool executive function measures.** ***Dimensional Change Card Sort Test (DCCS; NIH-TB, Weintraub et al., 2013).*** The DCCS is designed to measure cognitive flexibility or task switching. The participant is presented with target pictures that vary along two dimensions (shape and color). At the presentation of each picture, the participant is asked to sort according to one of its dimensions (e.g., color) for several trials. In switch trials, they are asked to sort according to its other dimension (e.g., shape). The dependent variable was a vector score combining accuracy and reaction time performance based on the algorithm provided by the NIH Toolbox (Slotkin et al., 2012). Prior to combining the accuracy and reaction time scores, a log (Base 10) transformation was applied to the reaction time data based on the mean reaction time score, and scores that fell out of the allowable range of 100 to 3,000ms were truncated to account for any floor or ceiling effects. Log values were then algebraically rescaled to a range of zero to five. Only accuracy scores of individuals who scored above 80% were used and algebraically scaled to five. Both the reaction time and accuracy scores were then combined and multiplied by ten for a scale maximum of 100.

***Flanker Inhibitory Control and Attention Test (ANT; NIH-TB, Weintraub et al., 2013).*** The ANT is designed to measure attention and inhibitory control. In this task, the participant is presented with a central arrow stimulus and two arrow stimuli flanking on both the left and right sides. The participant is instructed to attend to the middle arrow

that is either facing the same direction as the flanking arrows (congruent) or facing the opposite direction of the flanking arrows (incongruent). If the middle arrow is facing left, then the participant is instructed to press the left arrow key, and if the middle arrow is facing right, then the participant is instructed to press the right arrow key. The dependent variable was a vector score combining accuracy and reaction time performance (see DCCS task description for further details on vector score).

**Hot executive function measures.** ***Stoplight Task (STOP; Mather, Gorlick, & Lighthall, 2009).*** The Stoplight Task is a risk and reward test. It is a simulated driving test, projected from the perspective of the driver. The participants control how far they drive a vehicle along a straight track. The object of the test is to earn as many points as possible by having their car travel along the screen for as long as possible. During each round, the participant began with a green traffic light that turned yellow once they began to drive. The participants were told they had an unknown amount of time to drive their car before the traffic light would change from yellow to red. If they stopped the car before the light turned red, then they received all of the points from that round. However, if they did not stop their car before the light turned red, then they were "pulled over by the police" and lost all points for that round. The dependent variable (Gardner & Steinberg, 2005) was the standardized average of the following two variables: (a) the total number of restarts (i.e., stops followed by starts), and (b) the total amount of time the car was in motion, a participant who takes many risks will have a higher standardized average.

***Balloon Analogue Risk Task (BART; Lejuez et al., 2003).*** The BART is a risk and reward test. In this task, the participant was presented with a series of 30 balloons. For each balloon, the participant had a choice to inflate the balloon and accrue additional points or to stop inflating the balloon and bank the already accrued points. With each additional pump, the number of points increased, as did the probability of a burst. The dependent variables were (a) the average number of pumps for balloons which did not pop, and (b) the number of explosions (exploded balloons).

**Questionnaire measures**. ***Barratt Impulsiveness Scale Version 1(BIS; Patton, Stanford, & Barratt, 1995).*** The BIS was administered to allow for the examination of individual differences in impulsivity between adolescents. This scale assessed how impulsive an individual was based on his/her ratings on a series of statements (e.g., "I say things without thinking."). It contained 30 statements and participants were instructed to "answer quickly and honestly." To answer the statements, participants identified one of four options on a Likert-type scale: 1) Rarely/Never, 2) Occasionally, 3) Often, 4) Almost Always/Always. The dependent variable was the total of the summed responses. A higher sum indicates a greater level of impulsiveness.

***Zuckerman Sensation Seeking Scale (ZSS; Zuckerman, Eysenck, & Eysenck, 1978).*** The ZSS was administered to allow for the examination of individual differences in sensation seeking between adolescents This scale includes items that summarize sensation seeking attitudes. Five of the six questions were chosen as suitable for both younger and older adolescents (e.g., "I like doing things just for the thrill of it."). The

question removed was “I like wild and uninhibited parties,” because it did not seem age appropriate for the younger adolescents. This scale was administered a forced-choice true or false answer format. The dependent variable was the number of statements marked as “True.”

***Resistance to Peer Influence Scale (RPI; Steinberg & Monahan, 2007).*** The RPI was administered to allow for the examination of individual levels of resistance to peer influence between adolescents, and the examination of the relationship between one’s resistance to peer influence score and performance in the peer context. This is an eight-question scale in which the participant must decide which of two statements best applies to him/herself (e. g., “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 it will make their friends unhappy.”) After choosing the most accurate statement, he/she then marked whether the statement was “really true” or “sort of true.” The dependent variable was calculated from the number of times the participant marked agreed with the importance of going along with peer preference; a higher number indicated a greater susceptibility to peer influence.

***Peer Relation Survey (PRS)***. The PRS was administered to account for any random assignments where two individuals were close friends outside of the testing environment. This survey consists of three questions. Each participant was asked to fill out this form to indicate how well they knew the individuals in their assigned 3-person peer group. See Appendix B for additional details.

***MacArthur Scale of Subjective Social Status (MASS-F; MASS-I; Goodman, Adler, & Kawachi, 2001)***. The MSSS was administered to provide a more robust measure of family status due to the potential discrepancy between the reported household income of younger adolescents and older adolescents. Both groups may report different estimates of their family income, and older adolescents may differ in how they account for their parental income and their individual income. This scale consists of two ladders, each with an accompanying statement describing what the ladder rungs represented. The first ladder represented society. Participants were asked to identify where on the ladder their family best fit (e.g., the top rung of the ladder indicates the people in society with the best jobs, most respect, etc.). The second ladder represented the participants' schools, and they were asked to identify where on the ladder they best fit (e.g., the top rung of the ladder indicates the students with the best grades, most friends, etc.). The dependent variables consisted of the response for each ladder, with a higher score indicating greater perceived social status.

***Demographic Questionnaire***. The demographic questionnaire was administered so that each participant had a measure of sex, age, and language preference. This questionnaire consists of five questions assessing sex, age, race, family income, and language preference. Responses from this questionnaire are used to gather characteristics of the sample.

***The Petersen Development Scale (PDS; Petersen, Crockett, Richards, & Boxer, 1988b).*** The PDS was administered to account for individual differences relating to

puberty. In this scale participants were asked to indicate when they completed developmental stages related to pubertal onset. For females, the dependent variable was age at first menarche, and for males, the dependent variable was age of voice change.

***The Ten-Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003).*** The TIPI was administered to allow for the examination of individual differences in personality between adolescents. This is an abbreviated personality inventory. For each item, participants would read the adjectives and mark on a scale of one to seven how well each adjective described them. There were five dependent variables: (a) Extraversion, (b) Agreeableness, (c) Conscientiousness, (d) Emotional Stability, and (e) Openness to Experience.

***Parental Monitoring Questionnaire (PMS; Steinberg, Fletcher, & Darling, 1994).*** The PMQ was administered to allow for the examination of individual differences in reports of parental monitoring, particularly because there has been an increased interest in the role of parents on risk taking. Participants were presented with a series of activities/statements and asked to indicate how much their parents know about each. The dependent variable was the degree of parental monitoring. A higher number indicates a greater level of parental monitoring.

***Early Adolescent Temperament Questionnaire-Revised (EATQ; Ellis & Rothbart, 2001).*** The EATQ-r was administered to allow for the examination of individual differences in effortful control (EC) between adolescents, as well as to examine the role of EC on cool and hot EF performance. This measure was only

completed by individuals between the ages of 12 and 15. Participants read a series of statements and were asked to indicate how well they thought each statement applied to them on a scale of one to five. There were two dependent variables examined (composite-scale variables): Effortful Control (the average score of Attention, Inhibitory Control, and Activation Control), and Surgency (the average score of Surgency, Fear (reverse-scored), and Shyness (reverse-scored).

***Adult Temperament Questionnaire Short Form (ATQ; Rothbart, Ahadi, & Evans, 2000).*** The ATQ was administered to allow for the examination of individual differences in effortful control (EC) between adolescents, as well as to examine the role of EC on cool and hot EF performance. This measure was completed only by individuals between the ages of 18 and 21. Participants read a series of statements and were asked to indicate how well they thought each statement applied to them on a scale of one to seven. There were two dependent variables (composite-scale variables) examined: Effortful Control (the average score of Attention, Inhibitory Control, and Activation Control), and Surgency (the average score of Sociability, High Intensity Pleasure, and Positive Affect).

## Data Analysis

**Preliminary analyses**. To account for context order effects, one's random assignment to first complete the tasks in the alone context or in the peer context was included as a covariate in the analyses. To examine whether there were significant group differences on individual measures which needed to be accounted for in the analyses as a covariate, a between subjects (YA female; OA female; YA male; OA male) MANOVA

was computed for the following questionnaire measures: Resistance to Peer Influence (RPI), Barratt Impulsivity Scale (BIS), MacArthur Scale of Social Status-Family (MSSS-F), MacArthur Scale of Social Status-Individual (MSSS-I), Parental Monitoring Questionnaire (PMQ), Ten Item Personality Inventory (TIPI) of Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness, Early Adolescent Temperament Questionnaire Revised (EATQ-r) Surgency and Effortful Control, Adult Temperament Questionnaire Short (ATQ) Surgency and Effortful Control, and the Zuckerman Sensation Seeking Score. Of the thirteen measures, the following showed significant group differences: MSSS-I, $F(3, 90) = 3.929$, $p < .05$; PMQ, $F(3, 90) = 13.977$, $p < .01$; $TIPI_{Agreeableness}$, $F(3, 90) = 3.567$, $p < .05$; Effortful $Control^{EATQ\text{-}R;ATQ}$, $F(3, 90) = 4.518$, $p < .005$; and $Surgency_{EATQ\text{-}R;ATQ}$, $F(3, 90) = 9.702$, $p < .05$. Therefore order of performing the tasks within the peer context was not considered further. There were no other significant between subject effects with the other questionnaire measures ($p$'s between .06 and .87). Therefore MSSS-I, PMQ, $TIPI_{Agreeableness}$, and $Surgency_{EATQ\text{-}R;ATQ}$ and $Effortul\ Control_{EATQ\text{-}R;ATQ}$ will be included in further analyses.

Finally in the peer context, participants were either the first, second or third peer to perform the tasks. To examine whether peer order needed to be accounted for in the analysis, 2 (age group) by 2 (sex) by 3 (peer order) ANOVAs were computed for each of the four dependent measures. Only peer order and interaction with peer order are considered here. In none of the four tasks were there significant peer order main effects: DCCS, $F(2, 99) = .783$, *n.s.*; ANT, $F(2, 93) = .437$, *n.s.*; BART pumps adjusted, $F(2, 81)$

= 1.781, *n.s.*; BART explosions, $F(2, 83) = 1.073$, *n.s.*. There were also no significant interactions of peer order and either age group or sex (all *p*'s > .10). Therefore order of performing the tasks within the peer context was not considered further.

**Primary analyses.** For each of the four dependent measures, main effects and interactions of experimental context, age group, and sex were examined using a 2 (experimental context) by 2 (age group) by 2 (sex) repeated measures Analysis of Variance (ANOVA). For the peer context, only individuals who performed the task in the presence of two peers were included in the analyses. Individuals performing - 2.5 standard deviations from the overall mean for either cool executive function test were excluded from further analyses. Performance measures for both the DCCS and ANT were computed using an algorithm which weighted, standardized and summed one's accuracy and reaction time measures into a single numeric indicator (see description in methods section; Slotkin et al., 2012). In the BART, the dependent variables of interest were the average number of pumps on trials without explosions (e.g., Lejuez et al., 2003) and the mean number of explosions (Cavalca et al., 2013). In the STOP, the dependent variable of interest was the summed average time the car was in motion and the number of stops and restarts (Gardner & Steinberg, 2005).

# Chapter 4: Results

## Dimensional Change Card Sort Task (DCCS)

There were no significant performance differences on the DCCS due to experimental context ($M_{Alone}$= 88.24; $M_{Peer}$=89.17; $F$ (1, 92) = .85, *n.s.*). There was a marginally significant difference in DCCS performance due to age group ($M_{YA}$= 86.94; $M_{OA}$=90.65; $F$ (1, 92) = 3.62 , $p$ = .06), with older adolescents performing better than younger adolescents. There was not a significant main effect due to sex ($F$(1, 92) = .53, *n.s.*). The two- and three-way interaction(s) were not significant: context by age group, $F$(1, 92) = 2.75, *n.s.*; context by sex, $F$(1, 92) = .54, *n.s.*, and context, age group, and sex: $F$(1, 92)= 1.15, *n.s.*.

## Attention Network Task (ANT)

There was a significant performance difference on the ANT due to experimental context ($M_{Alone}$ = 96.87 ; $M_{Peer}$ = 97.11; $F$(1, 86) = 11.69, $p$ < .001), but not for age group or sex: age group, $F$ (1, 86) = 2.68, *n.s.;* sex, $F$(1, 86) = .05, *n.s.*. Regarding interactions, the context by age group interaction was not significant ($F$(1, 86) = 2.88, *n.s.*). However, both the two-way interaction of context by sex, and the three-way interaction between context, age group, and sex were significant: context by sex, $F$(1, 86) = 4.34, $p$ < .05, and context by age group by sex, $F$(1, 86) = 5.220, $p$ < .05.

Follow up Student Newman Keul's tests for the three-way interaction showed that YA males in the alone context performed significantly worse than the other groups (i.e.,

$q(8) = 6.73$, $p < .05$), but they improved significantly in the peer context and their context did not differ from the performance of the other groups (see Figure 3 for additional details).

[Insert Figure 3 About Here]

**Balloon Analogue Risk Task (BART)**

**BART: Average adjusted pumps.** There was a significant experimental context effect on the BART ($M_{Alone} = 5.95$ vs. $M_{Peer} = 6.44$; $F(1, 73) = 6.69$, $p < .05$). There was not a significant difference in performance due to age group or sex: age group, $F$ (1, 73) = 1.65, *n.s.*; sex, $F(1, 73) = .45$, *n.s.*. The two-way and three-way interaction(s) were also not significant: context by age group, $F$ (1, 73) = .34, *n.s.*; context by sex, $F(1, 73) = .57$, *n.s.*, age group by sex, $F$ (1, 73) = 1.80, *n.s.*; context by age group by sex, $F$ (1, 73) = .36, *n.s.*. Regarding the average adjusted pumps on the BART, participants did better in the peer context.

**BART: Explosions.** There was not a significant main effect of experimental context, age group, or sex in the BART: context, $F(1, 74) = .03$, *n.s.*; age group, $F(1, 74) = 2.81$, *n.s.*; sex, $F(1, 74) = 1.56$, *n.s.*. Neither were the two- or three-way interactions significant: context by age group, $F$ (1, 74) = .07, *n.s.*; context by sex, $F$ (1, 74) = .18,

*n.s.*; age group by sex, *F* (1, 74) = .13, *n.s.*; context by age group by sex, *F*(1, 74) = .41, *n.s.*.

**The Stoplight Task (STOP)**

There were no significant main effects: context, *F*(1, 52) = 3.091, *n.s;* age group, *F*(1, 52) =2.35, *n.s.;* sex, *F*(1, 52) = .41, *n.s.*. Nor were there significant two- or three-way interactions: context by age group, *F*(1, 52) = .92, *n.s.*; context by sex, *F*(1, 52) = .40, *n.s.*; age group by sex, *F*(1, 52) = .98, *n.s.;* and context by age group by sex, *F*(1, 52) = .92, *n.s.*.

# Chapter 5: Discussion

The assertion that peer presence should be considered in adolescent risk taking or hot executive function (EF) outcomes is not new, but it is novel for cool executive function (EF) measures. To date, no study has specifically examined the role of peer presence on cool EF performance. This study investigated the effect of peer presence on cool and hot measures of EF, including the DCCS, the ANT, the BART and the STOP, in a sample of 12 to 15 year olds and 18 to 21 year olds. These data provide support for the argument that peer presence affects cool executive function as well as hot EF, however, the effect in cool EF is not as straightforward as in hot EF, and is moderated by age and gender.

## Revisiting Study Hypotheses

The test of the hypothesis predicting enhanced performance on the cool EF tasks in the peer context was partially significant. While an experimental context effect was not present in the DCCS, for the ANT it was present in the interaction between experimental context by age group by sex. For the younger adolescent males, the interaction effect was in the predicted direction. In line with the proposed model, young adolescent males performed significantly better in the peer context. Additionally, their performance in the alone context was significantly worse than all other groups. This effect was only present in the younger adolescent males, neither the females nor the older adolescent males exhibited significant differences in performance due to experimental context. The lack of

a main context effect in the DCCS suggests that the presence of peers is not enough to account for differences in cognitive flexibility, but the presence of a significant effect in the ANT suggests that it might be for inhibitory control. Although there was a marginal age effect in the DCCS, with older adolescents performing better than younger adolescents, these findings do little to support the model.

There was a significant main effect of context on hot EF (i.e., the number of adjusted pumps on the BART). However, it was in contrast to the hypothesis, with participants improving performance in the peer context (they pumped the balloon a greater number of times without explosions) rather than in the alone context. While this finding appeared to go in the opposite direction of the proposed model, there are important distinctions that separate this result from the findings put forth by Steinberg and Gardner (2005) and Cavalca and colleagues (2013). First, the dependent variable used by Steinberg and Gardner (2005) did not yield significant differences in this study. Second, Cavalca and colleagues (2013) based their findings on the number of explosions rather than the number of adjusted pumps, which also failed to yield significant differences in this study. It may be that the number of adjusted pumps is a less straightforward measure of risk because it accounts only for the number of pumps in which an explosion does not occur. Adolescents with a higher adjusted pumps score may have chosen a more strategic approach which resulted in a lower level of explosions. The score and process behind it may be more akin to the dependent variable of the ANT or DCCS, with a higher score indicating improved performance. If such is the case then the

greater risk taking score in the alone context may actually be a greater performance score, and this would support the proposed model. Alternatively, it may also indicate risk aversion, with adolescents being more hesitant to pump up the balloon if any have exploded, and the less often they pump up the balloon, then the less likely the balloon is to explode resulting in a greater amount of adjusted pumps.

The hypothesis predicting there would be a main effect of sex on risk taking, with males taking greater risks than females was not significant. It may be that behavioral measures of risk do not capture an adolescent male's attention in the same way that a tangible experience, such as skateboarding, would.

**Strengths of the Current Study**

The present study used a within subjects design, which allowed for a direct comparison of task performance in the same participants for both the alone and peer context, the presence of randomly assigned peers who also completed the tasks, and a similar testing environment for both younger and older adolescents, a factor that Gardner and Steinberg's 2005 study was unable to include. Using a within subjects design allowed us to measure how the same participant performed both alone and with two peers. This ensured that any performance differences between the alone and peer context were not due to the possibility that the characteristics of people assigned to the alone condition were qualitatively different from those assigned to the peer condition, and that the effects observed were a reflection of the differences due to context. In the Gardner and Steinberg (2005) study, younger adolescents were recruited through community

centers and randomly assigned to either an alone or peer condition. However their older adolescents (i.e., youths) and adult participants were told to bring two peers with them to the testing session (Gardner & Steinberg, 2005, p. 627). In our attempt to more closely match the experiences of the younger and older adolescents, both age groups had their peers randomly assigned in an academic environment. For the younger adolescents, recruitment occurred in their classrooms and data collection took place in their schools, and for the older adolescents, recruitment occurred through flyers on campus and data collection took place on their university campus. The possibility that peers in the middle school or university setting might know each other was accounted for with the use of the Peer Relation Survey. Our efforts to match the experiences of the two age groups provided an additional level of confidence that age-related differences were due to characteristics of the group and not characteristics of the environment.

Of particular note in the present study was the noisiness of the testing environment, which may more closely match the setting in which teenagers engage in decision making, both inside and outside of the classroom. Overall, the findings from this study support the burgeoning literature on adolescent decision-making in ecological contexts, by differentiating the types of decision-making and the potential contributions of individual differences, such as age or sex, in susceptibility to peer presence.

**Addressing Unexpected Findings**

There were also reported findings that were not predicted, but still significant. One finding was a marginally significant main effect of age on the DCCS, in which younger

adolescents performed more poorly than older adolescents. The finding that older adolescents performed better on the DCCS was not surprising when one considers that both groups performed well and the difference was small. For the ANT, there was a gender by context effect: males performed better in the peer context. When age group was taken into consideration, it was the younger adolescent males, compared to the other groups, who performed significantly worse in the alone context. It may be that the younger adolescent males may lack motivation to do well on their own, but improve their when peers are watching. They may be more likely to improve their performance in the peer context because they are motivated to either impress their peers or to avoid embarrassment in front of their peers, and because their score is significantly less than the others in the alone context, then this effect is apparent.

**Considering the Implications of Peer Presence**

Regarding younger adolescent males, the significant interaction based on the experimental context, age, and gender provides additional support for this study's proposed model that peer presence can improve performance on cool measures of EF. Because younger adolescent males performed poorly in the absence of peers, it is likely they lacked motivation unless their peers were watching them. That this effect was only present in 12 to 15 year old males indicates that there is something unique to this particular demographic regarding the dependent measure of inhibitory control. It is interesting that while this group performed worse than all other groups in the absence of peers, their performance was still hovering around 95%. While the approximate 2%

performance increase due to peer presence is small, it does provide some of the first evidence that peers matter not only for social outcomes, but for cognitive outcomes.

Until recently, the role of peer influence on risk taking had only been examined behaviorally with the STOP test. Earlier this year, Lejuez and colleagues looked at the influence of virtual peer presence on adolescent risk taking on the BART in smokers and non-smokers (Cavalca et al., 2013). Similar to the present study, perceived peer presence was established as a significant influence on risk taking on the BART, however, the effect of peer presence was only present for those categorized as smokers (Cavalca et al., 2013). It was posited that the teenage smokers were more likely to be impulsive and therefore more susceptible to peer influence. However, sans peer presence there was not a significant difference in risk outcome measures between the smoker and non-smoker adolescent groups in their study. Similar to the current study, two dependent variables were examined, a standard measure (i.e., the number of adjusted pumps) and a less used measure (i.e., number of popped balloons), but it was only the less visited measure that yielded significant results. It is likely that individuals with a higher level of explosions were more likely to engage in pumping up the balloon after a recent explosion, while individuals with less explosions were more likely to reduce their number of pumps, and therefore subsequent explosions. While one group may not have minded the balloon explosion and continued to try earning points by pumping up the balloon, the other group may have had an aversion to the balloons exploding, and they may have been more motivated to avoid balloon explosions than to earn points. In this way, the less they

pumped the balloon, then the less likely the balloon was to explode, and this could explain both the lower number of explosions and higher number of adjusted pumps. Those that have a higher level of explosions, on the other hand, may not have a similarly high number of adjusted pumps. Their explosion score would be higher than their adjusted pumps score. Although they would be willing to take the risk, because the adjusted pump trials remove any trials with an exploded balloon, their endorsement of risk would not be reflected in the traditional measure.

It is possible that the STOP task did not yield a significant finding because it may not be a reliable measure of risk taking in younger adolescents. A driving task may not be as salient for younger adolescents compared to older adolescents. Both groups would be acquainted with the risk of blowing up a balloon too big, but the younger adolescents would not be as familiar with the risk of driving through a yellow light. This unfamiliarity may lead the younger adolescents to more closely adhere to the rules allowing them to stop before the light turns red. They may also be less motivated to continue accelerating their car once the light has switched from green to yellow, and this lack of motivation may reduce the overall number of lost points. In addition, the effect size from Gardner and Steinberg (2005) is on the smaller side with $r_{effect}$ size = .281 (p. 629). This indicates that the age groups showed a difference in behavioral risk taking that was rather small. Without a sample of comparable size to 306, the likelihood of finding a similar effect is quite low.

## Conclusion

While surveys and national statistics provide researchers with an outcome measure of adolescent decision making, such as underage drinking, this information does little to inform researchers about *how* the adolescent came to that decision. In the case of speeding, researchers can only infer why a teenager chose to speed, but an examination of how the teenager came to the decision is still needed. To understand risk taking and decision making in adolescence, researchers must be aware of how the adolescent's environment influences his/her cognitive processes and lead him/her to choose certain goals. This study contributes to this examination by exploring the contextual influences of peer presence on hot and cool measures of executive function in younger and older adolescents.

Findings from this study suggest that younger adolescent males show significant performance differences on measures of cognitive control when peers are present versus absent. The present study was designed to further the exploration of the role of peers in adolescent decision-making in not only hot executive function tasks, which are typically thought to elicit underlying reward mechanisms, but also cool executive function tasks. These findings illustrate that peer influence in not domain specific, pertaining only to situations of explicit risk and reward, but rather peer influence is domain general, extending beyond risky situations to pedestrian situations. This distinction is useful, because risky situations do not haphazardly appear, rather they develop out of everyday scenarios. Take for example, a commonplace situation of three teenage boys hanging out

after school. They may not intend to seek out a risky activity, such as underage drinking, but they may desire to impress each other. In this way, any one of them may propose an activity they perceive the others will consider cool, especially if they are still getting acquainted. One of them, for example, may suggest they sneak into his parent(s)' liquor cabinet or watch an R-rated movie. Or let us consider a group of females working in an afterschool job together. They are not close friends and were assigned to the same shift by their supervisor. The three of them have a series of tasks they must complete during their work shift. However, one of the girls expresses an opinion that the task is stupid and no one cares about it anyway. Her opinion may reduce the motivation of the others girls to complete the task, or they may complete the task in a haphazard manner to avoid having their co-worker view them in a negative light as well. On the other hand, one of the girls may express enthusiasm for the job, and while the other two girls may not feel as strongly about their position, they may want to be friends with her. Their desire for friendship might motivate them to do well on the task. In these examples, seemingly mundane environments shift into a risk or reward context due to peer presence; In a peer context, the risk of being viewed negatively or the reward of being viewed positively by one's peers is ever present.

The current study supports the importance of considering peer influence as a domain general mechanism during adolescence. Whether specific situations typically engage cool executive function processes for children and adults, it is clear from this and other studies that cool executive function may only exist for adolescents in solitary

conditions. Otherwise performance patterns between the alone and peer context would not have varied on the ANT. In the future it is worth considering how, rather than if, specific cognitive mechanisms are influenced by peers. If better understood, peer presence could be used to positively effect change in adolescent cognition and behavior. Peer approval may provide incentives where adults have not found appropriate motivators and positive peer approval could replace dangerous forms of reward and decrease problematic behaviors. If teenagers believed that positive behaviors like volunteering or biking could impress their peers, then they may be more likely to engage in those behaviors and potentially forego more debilitating ones like underage drinking. Either way, peer presence is a major component of adolescence, including cognitive development.

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Table 1

Behavioral Test Sample Sizes

| Test | YA (F) | OA (F) |
|---|---|---|
| DCCS | 50 (12) | 55(31) |
| ANT | 43 (19) | 55 (33) |
| BART | 38 (18) | 45 (26) |
| STOP | 20 (10) | 42 (26) |

*Only individuals with two peers of the same gender were included in analyses.

Table 2.1

Demographic Details of Younger Adolescents

| Sex | Mean Age (*SD*) | Pubertal Onset (Range)* | English (Other) | White | American Indian | Hispanic | Black | Other |
|---|---|---|---|---|---|---|---|---|
| Male | 12.9 (.74) | 10.42-14.75 | 29 (-) | 25 | 2 | - | 1 | - |
| Female | 12.9 (.72) | 10.75-13.58 | 20 (1) | 19 | - | 2 | - | 1 |

*Note.* A column for Asian individuals was excluded because the cell size was zero.

*Range not applicable for individuals who have not experienced menarche (n = 5) or a height spurt (n = 8).

Table 2.2

*Demographic Details of Older Adolescents*

| Sex | Mean Age (*SD*) | Pubertal Onset (Range)* | English (Other) | White | Asian | Hispanic | Other |
|---|---|---|---|---|---|---|---|
| Male | 19.27 (1.12) | 11.0 – 21.75 | 20 (4) | 15 | 4 | 3 | - |
| Female | 19.11 (1.06) | 10.25-15.50 | 27 (9) | 25 | 11 | - | 1 |

*Note.* Columns for American Indian and Black Individuals were excluded, because the cell size was zero.

*Range not applicable for individuals who have not experienced menarche (n = 1) or a height spurt (n = 1).

Figure 1. Proposed model of peer influence on executive function performance.

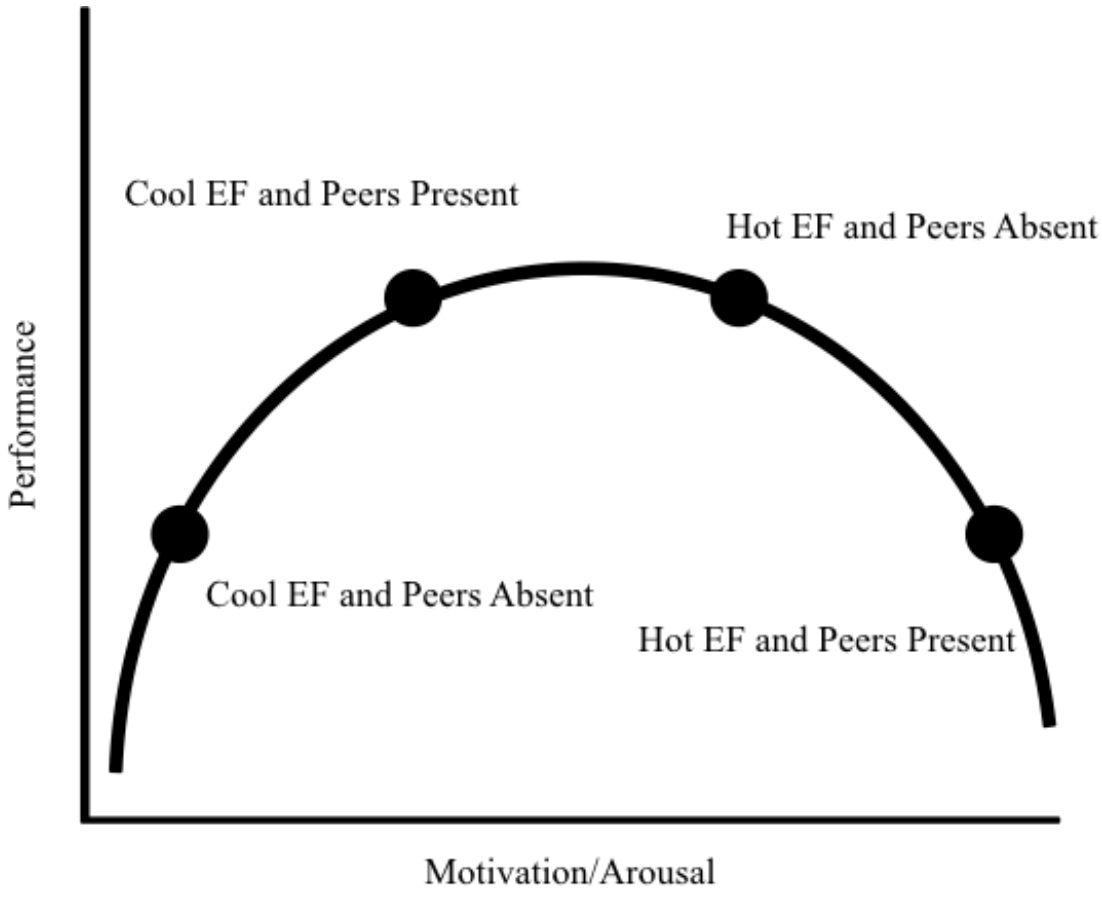


*Figure 1.* Akin to the Yerkes-Dodson Model, when considering adolescent performance and motivation/arousal, the relationship between arousal/motivation and performance on cool and hot EF measures may follow an inverted U-curve. Cool EF tasks, and the absence of external motivation, such as peers, may lead to little motivation/arousal and consequently poor performance, however, cool EF tasks and the presence of peers, may increase motivation/arousal and therefore performance. Hot EF tasks may already provide motivation/arousal, and performance would be better with peers absent. On the hot EF tasks, the presence of peers may increase motivation/arousal and decrease performance.

Figure 2a. Details of Alone Context

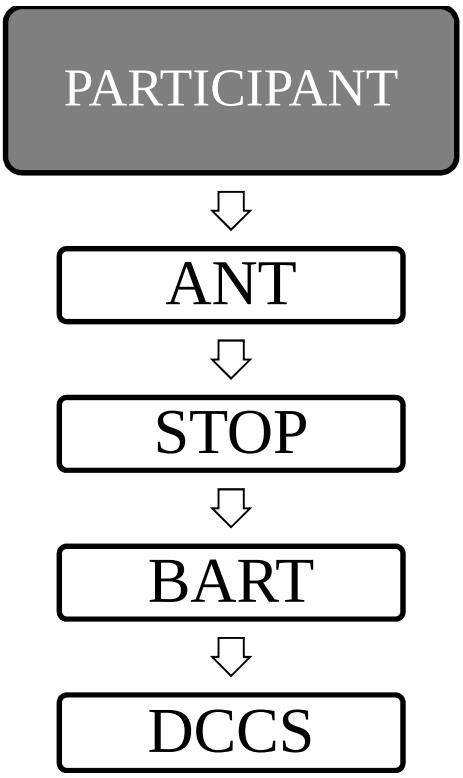


*Figure 2a*. During the Alone Context, the participant was randomly assigned to complete the four behavioral tests in one of four counterbalanced orders.

Figure 2a. Details of Alone Context

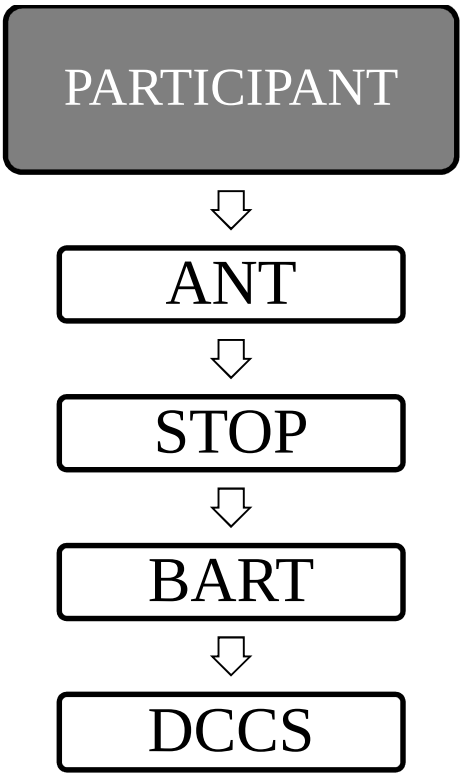


*Figure 2a*. During the Alone Context, the participant was randomly assigned to complete the four behavioral tests in one of four counterbalanced orders.

*Figure 2b. Details of Peer Context*

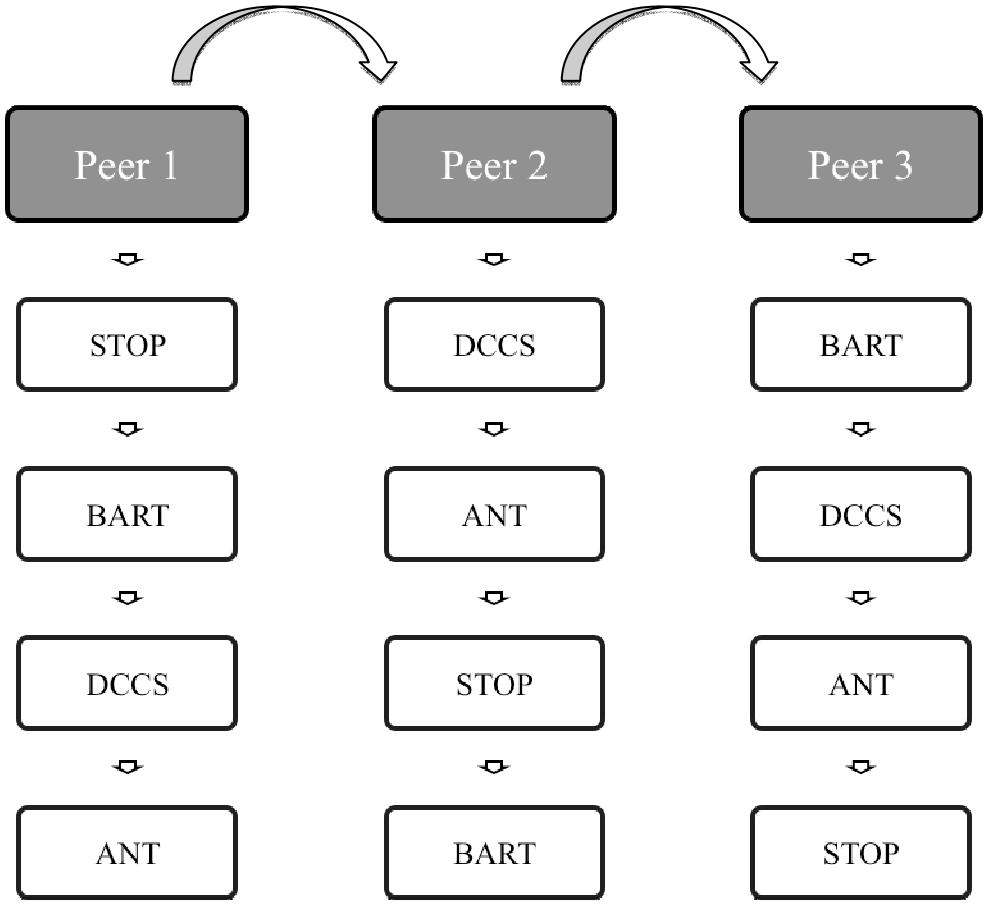


*Figure 2b.* Prior to the Peer Context, each participant is assigned as Peer 1, Peer 2, or Peer 3. Each was also randomly assigned to complete the four behavioral tests in one of four counterbalanced orders.

*Figure 3. ANT Performance Based on Context, Age Group, and Sex*

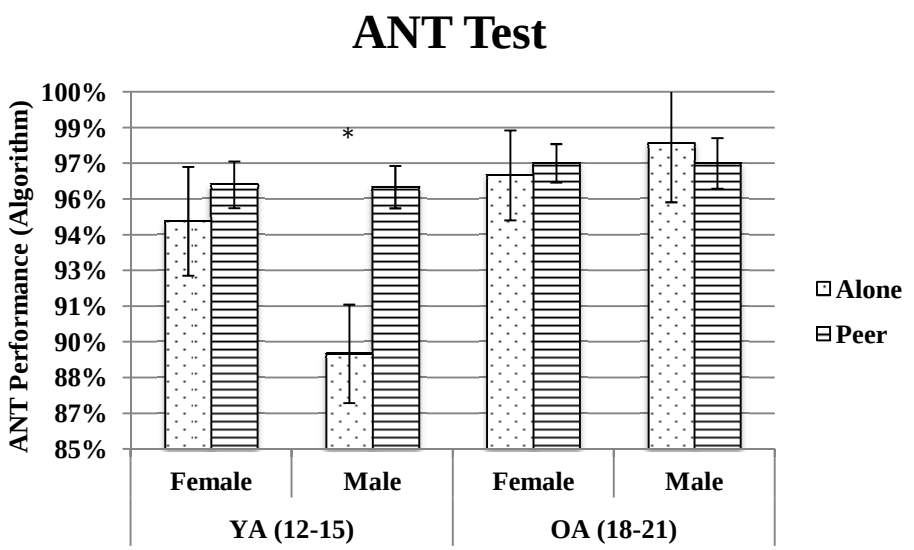


*Figure 3.* On the ANT Test, a measure of inhibitory control, YA males performed significantly better in the Peer Context than they did in the Alone Context ($p < .05$). On follow up Student Newman Keul's Tests, YA males performed significantly worse than all other groups when they were in the Alone Context, while in the Peer Context, YA males performed no differently than the other groups.

## Appendix A

## Participant Recruitment Methods

**Younger Adolescents.** Recruitment for younger adolescents relied on two channels. A subset was recruited through the Institute of Child Development's Infant Participant Pool (IPP). While the majority of 12 to 15 year old participants were contacted and recruited through their middle school.

Sessions scheduled with individuals recruited through the IPP list relied on the coordination of three participants' schedules. The research session was scheduled based on the availability of the first volunteer. Depending on the gender of the first volunteer, all future calls were made to adolescents of the same gender until two to three additional volunteers were scheduled. When possible, four volunteers would be scheduled to ensure that the session could be completed if one participant canceled. Using this method, six females and three males were recruited.

Much of the recruitment through the middle schools relied on publicly available phone numbers and email addresses. 25 middle school principals/supervisors were contacted and asked if they would be interested in having their students participate in an after school research session examining the role of peer influence on decision making. Of the 25 schools contacted, six expressed an interest in having their students

participate. A research session schedule was created with the principal/supervisor and computer lab technician. Principals/supervisors were then sent a parental consent form and asked to send these to all parents of 12 to 15 year olds. A number and email address was provided to all parents should they have any questions. Once these consent forms were sent to parents, the assistant to the principal/supervisor would create a list of students whose parents submitted consent forms. Based on each school's timeline (e.g. some schools provided a list of students a week before the research session, while others provided them the day of the research session), volunteers would be assigned a participant identification number and a peer group. At the research session, younger adolescents were asked to fill out an assent form and were provided with a ten dollar gift card.

**Older Adolescents.** Participants, aged 18-21 years old were recruited from the University of Minnesota campus through the use of flyers and tabling. They were also recruited through the University of Minnesota's Psychology Department Research Experience Points (REP) website. Participant's schedules were coordinated ahead of time. Their participant identification number and peer assignment were contingent on when they signed up for the research session. Consent was obtained from each participant and compensation of ten dollars or two REP points were provided.

## Appendix B

### Peer Relation Survey

| Peer Relation Survey |
| --- |
| Directions: Answer the following questions by circling the answer. Make sure to carefully read questions **two** and **three**. Not every participant will answer them. |

1. Did you know this person before today?

No Yes

2. If circled **Yes**, how well do you claim to know this person?

Acquaintance Friend

3. If circled **Friend**, how close are you to this friend?

| 1 | 2 | 3 | 4 | 5 |
| --- | --- | --- | --- | --- |
| Not Close | Kind of Close | Close | Very Close | Extremely Close |