SUSCEPTIBILITY TO PEER INFLUENCE, SOCIAL EXCLUSION, AND ADOLESCENT RISKY DECISIONS

by

SHANNON JAY PEAKE

A DISSERTATION

Presented to the Department of Psychology
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

December 2015

DISSERTATION APPROVAL PAGE

Student: Shannon Jay Peake

Title: Susceptibility to Peer Influence, Social Exclusion, and Adolescent Risky Decisions

This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Psychology by:

Jennifer H. Pfeifer	Chairperson
Philip A. Fisher	Core Member
Nick B. Allen	Core Member
Elliot T. Berkman	Core Member
Leslie Leve	Institutional Representative

and

Scott L. Pratt	Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

Degree awarded December 2015

DISSERTATION ABSTRACT

Shannon Jay Peake

Doctor of Psychology

Department of Psychology

December 2015

Title: Susceptibility to Peer Influence, Social Exclusion, and Adolescent Risky Decisions

Understanding the mechanisms of poor decision making and risk behavior in adolescence is an important goal. Two important features of adolescence relevant to these concerns are the saliency of social acceptance and increased frequency of making decisions in the company of peers. The current study examines individual differences in susceptibility to peer influence and the effect of positive and negative social contexts on adolescent decision making. Fifty-five adolescents (11.2-17.6 years of age) completed measures of social susceptibility and risk behavior and subsequently underwent functional magnetic resonance imaging while completing a simulated driving game in three conditions: alone, while being watched by peers, and after an event of social exclusion. Individual differences in susceptibility to peers predicted a decrease in adaptive decision making following exclusion by peers. Adolescents with greater self-reported engagement in substance use, risky sexual behavior, and aggressive behavior performed worse on the game following social exclusion.

Neuroimaging results showed relatively greater activation in the striatum during risky decisions (Go through a yellow light) in the peer condition compared to the social exclusion condition. Whole-brain and region of interest analyses revealed a significant decrease in striatal activity during Go decisions following social exclusion. Adolescents who were more susceptible to peer influence and engaged in more risk behavior evidenced the greatest decreases in striatal activity after social exclusion. Results suggest that susceptibility to peer influence interacts with the experience of social exclusion to produce maladaptive decision making in adolescents.

More broadly, the results demonstrate that individual differences and social contexts are both important factors affecting adolescent decisions and that changes in momentary levels of social acceptance can influence the quality of adolescent decisions in social situations. These findings suggest that the explanatory power of existing models of adolescent decision making could be extended by exploring individual differences in decision making within and across social contexts, including peer influence and social exclusion, to provide a more comprehensive account of which adolescents are prone to making poor decisions and when.

CURRICULUM VITAE

NAME OF AUTHOR: Shannon Jay Peake

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene
Washington State University, Vancouver

DEGREES AWARDED:

Doctor of Philosophy in Psychology, 2015, University of Oregon
Master of Science in Psychology, 2010, University of Oregon
Bachelor of Science in Psychology, 2008, Washington State University, Vancouver

PROFESSIONAL EXPERIENCE:

Family Therapist and Parent Group Facilitator, Prevention Science Institute and OSLC Community Programs. March 2014 to September 2015.

NIDA Translational Drug Abuse and Prevention Graduate Research Fellow, Prevention Science Institute, University of Oregon. September 2013 to September 2015.

NIH Development and Psychopathology Research Training Fellow, Child & Family Center, University of Oregon. June 2009 to May 2011.

PUBLICATIONS:

Kahn, L. E., Peake, S. J., Dishion, T. J., Stormshak, E. A., & Pfeifer, J. H. (2014). Learning to play it safe (or not): stable and evolving neural responses during adolescent risky decision-making. *Journal of Cognitive Neuroscience*, 27(1), 13-25. doi:10.1162/jocn_a_00694

Peake, S. J., Dishion, T. J., Stormshak, E. A., Moore, W. E., & Pfeifer, J. H. (2013). Risk-taking and social exclusion in adolescence: Neural mechanisms underlying peer influences on decision-making. *NeuroImage, 82*, 23-34.

Pfeifer, J. H., Kahn, L. E., Merchant, J. S., Peake, S. J., Veroude, K., Masten, C. L., Lieberman, M. D., Mazziotta, J. C., & Dapretto, M. (2013). Longitudinal change in the neural bases of adolescent social self-evaluations: Effects of age and pubertal development. *Journal of Neuroscience, 33*(17), 7415-7419.

Bruce J., Fisher P. A., Graham A. M., Moore W. E., Peake S. J., & Mannering A. M. (2013). Patterns of brain activation in foster children and nonmaltreated children during an inhibitory control task. *Development & Psychopathology, 25*(4pt1), 931-941.

Pfeifer, J. H., & Peake, S. J. (2012). Self-development: Integrating cognitive, socioemotional, and neuroimaging perspectives. *Developmental Cognitive Neuroscience*, *2*(1), 55-69. doi: 10.1016/j.dcn.2011.07.012

ACKNOWLEDGMENTS

I wish to express my heartfelt thanks to my advisor, Jennifer Pfeifer, and the members of my committee for their valuable feedback during the preparation of this manuscript. In addition, special thanks are due to Lori Olsen whose mastery of the doctoral program requirements and unfailing good humor were indispensable. The investigation was supported in part by a National Institute on Drug Abuse center grant, Number 1P50DA035763-01 to Drs. Jennifer Pfeifer and Philip Fisher at the University of Oregon.

To my mother, who never gave up hope.

TABLE OF CONTENTS

Chapter Page

Chapter Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Adolescence is a period during which teens are given increasing autonomy to make decisions. These emerging decision-making skills are applied to actions with potentially long term consequences, such as substance use, sexual behavior, and risky or incapacitated driving. The disproportionately high rates of engagement in potentially harmful activities during adolescence relative to childhood or adulthood represent an area of concern for public health and adolescent wellbeing (Eaton et al., 2012). In addition, many of these choices will be made in situations involving other adolescents, highlighting the increasing relevance of social consequences of decisions and outcomes (Dishion, Ha, & Véronneau, 2012; Simons-Morton, Lerner, & Singer, 2005).

However, not all adolescents engage in excessive risk behavior, and even those that do so, only make poor decisions some of the time. A critical next step for research is to determine which adolescents are prone to making poor decisions, when (in what situations) and how poor decisions are more likely to occur. In an effort to contribute to these research questions, the goals of this dissertation are to examine individual differences associated with excessive risk behaviors, particularly as they relate to the influence of social contexts on decisions and the mechanisms through which they operate. In the domain of adolescent behavior, individual differences will be represented by behavioral outcomes and psychological traits that predict current or future maladaptive decisions (i.e., real-world risk). Social contexts will include situations involving positive interactions with peers as well as, critically, social exclusion by peers. The particular mechanisms examined will be cognitive factors such as reward sensitivity, motivation, cognitive control, social cognition, and their associated profiles of neural activity.

Models of Neurological Development

Neurobiological models examine behavioral and physiological indices of risk decisions, including structural and functional aspects of brain development using imaging technologies, such as magnetic resonance imaging (MRI). These perspectives suggest that adolescence is a time of heightened sensitivity to reward and affective systems in the brain coupled with immature development of self-regulation and inhibitory control systems (Casey, Jones, & Somerville, 2011; Ernst, Romeo, & Andersen, 2009; Somerville, Jones, & Casey, 2010; Steinberg, 2010). The imbalance between these systems is proposed to result in disproportionate levels of risk-taking during adolescence. Some variability exists among these imbalance models. The Triadic Model (Ernst & Fudge, 2009) posits the involvement of three functional processes and their associated neural structures, that act in balance to support approach (striatum), avoidance (amygdala), and modulation (prefrontal cortex) of behavior. Other views focus primarily on two systems supporting affective and motivational processing in subcortical limbic regions (striatum), and cognitive control in cortical regions (prefrontal cortex; (Casey et al., 2011)) or a socioemotional system in limbic and paralimbic areas and a cognitive control system comprised of lateral prefrontal and parietal cortex areas (Steinberg, 2010).

These perspectives all share the view that the striatum is consistently implicated in reward and motivation: two fundamental components of decisions and actions in both adults (Christopoulos, Tobler, Bossaerts, Dolan, & Schultz, 2009) and adolescents (Cohen et al., 2010; Ernst et al., 2005; Galvan et al., 2006; May et al., 2004; Van Leijenhorst et al., 2010). Many studies have examined the effects of age and different decision parameters on striatal response, and the broad consensus on the functional role of the striatum in reward value and motivation makes it a good choice for assessing differences in decision values (Knutson, Delgado, & Phillips, 2008; Wendler et al., 2013). Another important function attributed to the striatum is facilitation of motor response, (Grillner, Hellgren, Menard, Saitoh, & Wikström, 2005) a key element in many decision and cognitive tasks.

A key premise of this dissertation is that changes in social context, such as the experience of social exclusion, can alter the decision value of certain actions available to adolescents, resulting in a shift in behavioral response. This view posits that these shifts in behavior will be reflected in altered patterns of activity in structures associated with reward and motivation, such as the striatum.

More recent reviews have acknowledged the influence of state and trait factors associated with the individual and with the context of the decision (Bjork, Lynne-Landsman, Sirocco, & Boyce, 2012; Richards, Plate, & Ernst, 2013). In sum, consideration of the affective and motivational influences of social factors in conjunction with cognitive and neurobiological factors represents a promising trend in the study of adolescent risk decisions.

The Effects of Social Context and Individual Differences in Adolescent Decision Making

This emerging focus of research has led to examinations of the effects of social contexts (Charles & Blum, 2008) and individual differences on behavioral and neural response in adolescent decision making. An important aspect of social contexts is the influence of peers on teen behavior (Brechwald & Prinstein, 2011). Although many approaches to the study of peer influence have been used, one of the most salient illustrations has been from studies that compare adolescent decisions made while alone to decisions when being watched by peers. Several studies have shown that the mere presence of peers affects adolescent performance on laboratory tasks (Cavalca et al., 2013; Gardner & Steinberg, 2005a; Haddad, Harrison, Norman, & Lau, 2014) and when actually driving (Carter, Bingham, Zakrajsek, Shope, & Sayer, 2014; Simons-Morton et al., 2005), including demonstrating an increased preference for immediate rewards when in the company of peers (O'Brien, Albert, Chein, & Steinberg, 2011). These studies point to the importance of social contexts in influencing adolescent decisions.

Contexts involving social evaluation or exclusion also affect decisions. Research broadly shows that stress from social evaluation results in decreased performance on laboratory tasks and changes in risk decisions (Figner, Mackinlay, Wilkening, & Weber, 2009; Reynolds et al., 2013; Somerville, Kelley, & Heatherton, 2010; Stroud et al., 2009). Falk and colleagues (Falk et al., 2014) found that increased distress during social exclusion predicted increased risky driving in the presence of a peer. Additionally, responses to social exclusion in brain regions associated with social cognition predicted risky driving in adolescents over one week later. A range of other studies have shown that responses to social rejection or exclusion include taking irrational, self-defeating risks (Twenge, Catanese, & Baumeister, 2002), decreased self-regulation (DeWall, Baumeister, & Vohs, 2008; Oaten, Williams, Jones, & Zadro, 2008), lower prosocial behavior (Mallott, Maner, DeWall, & Schmidt, 2009), and increased aggression (Ayduk, Gyurak, & Luerssen, 2008). Meanwhile, evidence of individual differences in potential positive responses include increased attention to social cues (DeWall, Maner, & Rouby, 2009), greater susceptibility to social influence (Carter-Sowell, Chen, & Williams, 2008), and attempts to form new social connections (Maner, DeWall, Baumeister, & Schaller, 2007).

Individual differences have also been found for susceptibility to peer influence and for poor decision making in risk tasks. Teens vary substantially on the degree to which they are willing to alter their endorsement of risky behavior to be more like that of high-status peers (Prinstein, Brechwald, & Cohen, 2011) and to change their actual risk behavior to conform to that of their peers (Allen, Chango, Szwedo, Schad, & Marston, 2012). Some individual differences relate to behavioral differences on laboratory tasks that predict real world risk. One such study (Rao et al., 2011) found that, although performance on a risk decision task was similar between adults and adolescents, about one-third of the adolescents made significantly more high-risk choices than other adolescents, and that the preference for risk choices predicted real-life risk and substance use problems. Performance on other risk decision tasks also predicts health-risking behaviors, such as smoking (Lejuez, Aklin, Bornovalova, & Moolchan, 2005), drug use (Aklin, Lejuez, Zvolensky, Kahler, & Gwadz, 2005; Hopko et al., 2006), and risky sexual behavior (Lejuez, Simmons, Aklin, Daughters, & Dvir, 2004), and risky driving (Scott-Parker, Watson, & King, 2009; Shope & Bingham, 2008). Collectively, research into the effects of social context and individual differences provides a compelling rationale for their use in informing developmental theories of adolescent risk.

Motivation for the Current Study

The behaviors potentially arising from poor decisions can have serious outcomes with potentially long term negative consequences for adolescents. Expanding our knowledge of the mechanisms associated with maladaptive decision making in adolescents is an important first step in understanding how to support teens in being more resilient and less susceptible to influence in risky situations.

Based on the above review, substantial evidence exists that social contexts, such as peer influence, social evaluation, and social exclusion can lead to changes in how adolescents make decisions in ways that are potentially harmful. There are also clear examples of how individual differences in traits, such as susceptibilty to peer influence, in patterns of response to behavioral tasks, and in response to social situations like the presence of peers can alter adolescent decisions.

The primary purpose of this dissertation is to assess the influence of social context and individual differences on adolescent decision making and how those factors relate to actual risk behavior. To accomplish that, a procedure was designed to obtain behavioral and neuroimaging measures of decision making in three different situations: alone, being watched by peers, and after being excluded by peers. The effect of each condition was measured by differences in decisions and performance on the behavioral task and related profiles of neural activity collected while subjects completed the tasks in a magnetic resonance imaging (MRI) scanner. Individual differences were assessed using standard measures of social susceptibility and motivation, as well as measures of actual risk behavior and control variables.

At least as important as the design and implementation of the social context manipulations was the design and development of an effective decision making task, and this topic merits a thorough explanation. Although the justification for examining the effects of social context and individual differences in adolescent decision making is clear, implementation of that goal requires a behavioral task that adequately assesses those influences. Thus, a key element in assessing adolescent decision making is the selection of a risk task and interpretation of behavioral results. Tasks vary on many factors, including whether the decision is ambiguous (unstated risk probability) or uncertain (explicitly stated risk probability), what type of reward is available (monetary, game performance), and the configuration of probabilities between choice options (Richards et al., 2013). Many studies of adolescent risk employ tasks derived from classical behavior economics in which probabilities are expressly stated and subjects select between options of different values and risks (Schonberg, Fox, & Poldrack, 2011).

An important consideration is to identify tasks that are able to capture aspects of adolescent decisions that bear a relation to their actual risk behavior. Accordingly, the choice and the design of the risk task was selected to approximate, to the extent possible, the features of decisions teens might make in real social situations. Because risk decisions are necessary for normal development (Dworkin, 2005; Jessor & Jessor, 1975), and because decision factors are ambiguous in many social situations, the challenge for adolescents is to know which risks are appropriate and when. Likewise, the distinction between adaptive and maladaptive decisions is crucial when interpreting the results of various risk tasks. Each task generally posits that a certain behavior (e.g., choosing an option with greater risk variability or choosing a reward option that carries the risk of some loss) represents risk behavior. While that may meet the classical economic definition of risk as any option with greater variability (Weber, Shafir, & Blais, 2004), in many cases, choosing the “risky” option results in better performance on the task. Although the term "risky" is often equated with being unsafe in the clinical psychology literature (Schonberg et al., 2011), some risky decisions are in fact adaptive and should be interpreted as indicators of decision-making competence. As a result, many economic risk tasks are poor predictors of an individual's actual risk decisions (, 2011). The current study takes the view that it is less useful to judge whether a decision is risky or not, but rather whether it is adaptive or maladaptive in the current context. This is the difficulty adolescents face every day as they navigate complex social situations. It also leads to the premise that real-life risk may be associated with maladaptive choices regardless of whether they involve higher or lower levels of risk.

It is hypothesized that the interaction of social context and individual differences in social susceptibility will exert an effect on decision making; specifically, that adolescents who are more influenced by peers will take more risks when in the presence of peers. This would provide additional support for studies showing similar effects of peer influence (Chein, Albert, OBrien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005; Peake, Dishion, Stormshak, Moore, & Pfeifer, 2013). Critically, however, it is also hypothesized that a negative social context, such as an experience of social exclusion by peers, will also affect decision making. The direction of this effect in terms of increased or decreased risk is uncertain, because, as stated in the rationale for the behavioral task above, the distinction between risk and adaptive decision making is unclear in many "risk tasks." However, it is hypothesized that the context of social exclusion will be associated with a decrease in *adaptive* risk, revealed by overall performance on the task. At the neural level, it is hypothesized that changes in decisions will be related to altered patterns of activation in the striatum, as an indicator of changes in reward and motivation, and possibly in temporoparietal junction, as an indicator of increased social cognition representing activity associated with mentalizing (i.e. thinking about what others are thinking). These predictions are based partly on the literature for peer interactions and partly on results from our previous work (Peake et al., 2013).

CHAPTER II

METHODS

Participants

Fifty-nine adolescents participated in the experiment. Four subjects were excluded: two for excessive motion (greater than 2 mm maximum translation or rotation movement in any single dimension), one for insufficient events in a condition (no Go decisions in the Peer condition), and one for a corrupt imaging file. The remaining 55 participants (26 girls, 29 boys, 11.2-17.6 years old, M = 14.3, SD = 1.6) were included in the following analyses. All subjects reported no history of neurological or psychiatric disorders and no MRI contraindications. Five participants were left-handed and were included because the main processes of interest are predominately bilateral. All parents of participants provided written consent, and adolescent participants provided written assent, approved by the University of Oregon Institutional Review Board. Following the study, all adolescent participants were debriefed and received monetary compensation.

Task Descriptions

Yellow Light Game. Decision-making was assessed with the Yellow Light Game (YLG), adapted and substantially revised from the Stoplight Game (Gardner & Steinberg, 2005), a computerized driving task used in two recent fMRI studies with adolescents (Chein et al., 2011; Peake et al., 2013). In the YLG, subjects must drive along a course punctuated by many traffic intersections (in this case, 20 per run), with the goal of the fastest time possible. At every intersection, the traffic light turned yellow. Subjects were required to decide to either stop the car (Stop) or go through the intersection (Go); no steering or accelerating options were possible. A Stop decision resulted in a 2.5 second delay while the subject's car waited for the light to turn from red to green (Figure 1), resulting in a relatively slow overall time for that intersection. A Go decision could yield the fastest time with no stopping or waiting, but also carried the risk of crashing if a car came along the cross street. Crashing resulted in a 5.0 second delay, making the time spent at that intersection slower than if the subject had stopped for the red light. If subjects failed to make any choice (Stop or Go) before their car entered the intersection, they received a 7.5 second penalty, which resulted in the slowest overall time for the intersection. Subjects were presented with their overall time needed to complete the course and the number of crashes at the end of each round. Timing of the onset of the yellow and red lights and the presence or absence of a car on the cross street varied within a canonical set of 20 intersections, which were then randomized in order, to create 8 different round configurations. The order of rounds was randomized for each subject. The cumulative probability of crashing across all intersections of each round was 50% (i.e., ten intersections out of every twenty had cars approaching on the cross street, resulting in a crash if the subject made a Go decision), but this information was not explicitly stated to subjects. In four of these intersections, the light turned yellow earlier (i.e., further away from the intersection), and these intersections had a 75% probability of crashing if the participant makes a Go decision (three of four had cars approaching on the cross

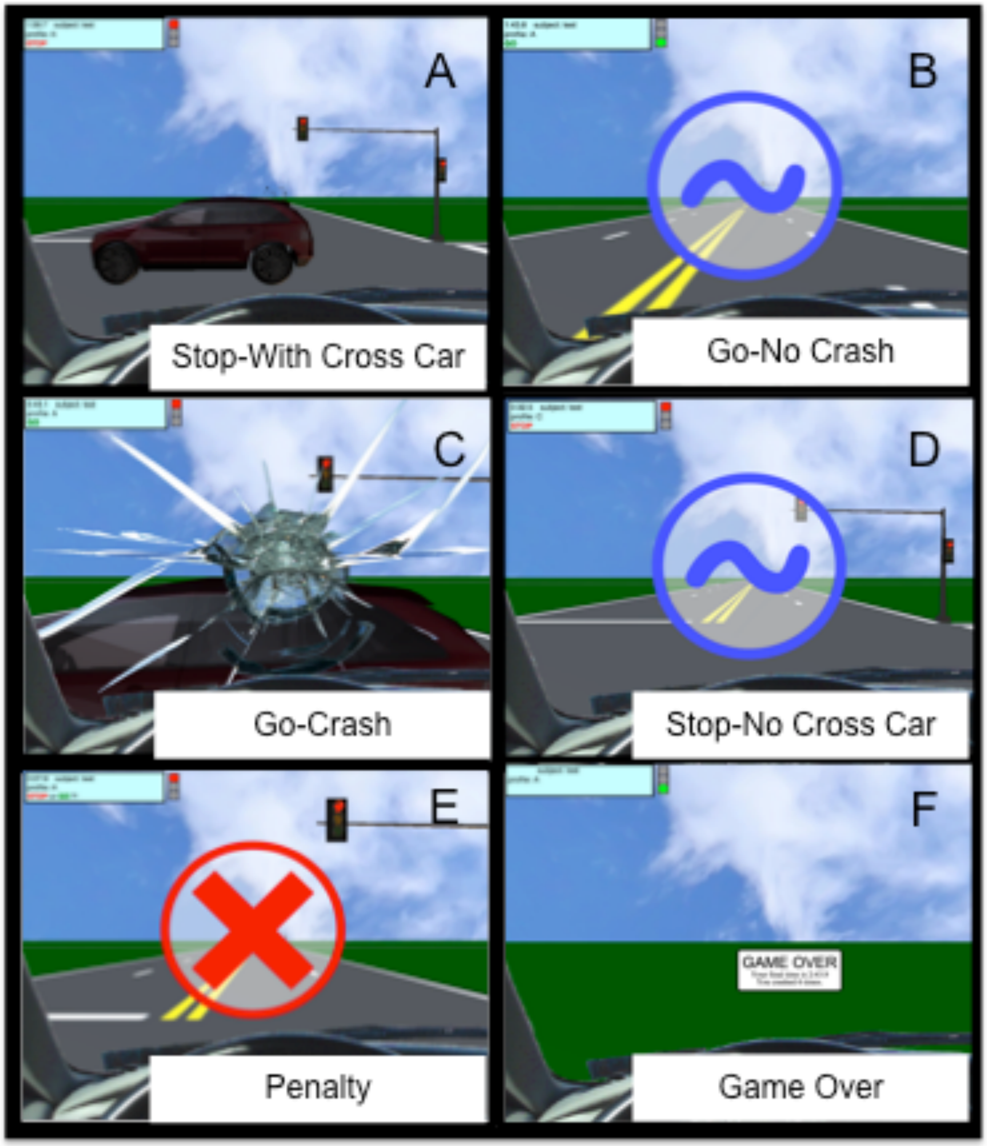

Figure 1. Yellow Light Game outcomes. A. Stop decision for an intersection with a crosscar. The cross car sounds a horn as it passes (2.5 sec. delay). B. Go decision for an intersection with no cross car. The blue tilde "No Car" symbols displays and a "No Car" sound plays while the subject car is stopped at the light (2.5 sec. delay).. C. Go decision with a cross car present. The cross car appears and the windshield cracks while a skidding car crash sound plays (5 sec. delay). D. Stop decision with no cross car. The blue tilde "No Car" symbols displays and a "No Car" sound plays while the subject car is still driving (no delay). E. Penalty for no decision before the intersection. The red X penalty symbol displays while a glaring buzzer penalty plays (7.5 sec. delay). F.Game Over. Subject time on the game and number of crashes is displayed.

street). In the other four intersections, the light turned yellow later (i.e., closer to the intersection), and these intersections had a 25% probability of crashing (only one of four had cars approaching on the cross street). On the remaining 12 intersections of the run, the light turned yellow at a middling distance from the intersection (in between ‘early’ and ‘late’ yellow lights described above), and these intersections had a 50% probability of crashing (six of twelve had cars approaching on the cross street). Thus, the configuration of intersections with different onsets of the yellow light provided a predictive visual cue of the different crash probabilities. This enabled tracking of participants’ ability to learn and attend to subtle contextual cues during risk decisions across rounds. Pilot sessions for our prior study (, 2013), and other previous studies using the Stoplight Task (Chein et al., 2011), found practice effects in the form of more Go decisions and more variability in behavioral performance during initial rounds of the task, followed by fewer Go decisions and more stable patterns thereafter. To reduce these effects, two practice rounds were included in the proposed study to allow behavioral performance to stabilize. Practice rounds were completed with no peers watching to establish a measure of baseline risk prior to the peer and social exclusion conditions. These “Practice” rounds were completed in a mock scanner to allow the participant to learn and practice the YLG in a scanner-like environment. The following six rounds were completed in the real MRI scanner in three conditions (“Alone,” “Peer,” “Social Exclusion”; see the section on Task Sequence below for condition descriptions). The primary outcomes for the YLG were scores computed across the three conditions for Go and Stop decisions and game performance (time to complete a single round of 20 intersections). Additional behavioral variables were examined that linked decisions with specific outcomes: number of Hits (Go decisions with no car present), Misses (Go decision with crash), False Alarms (Stop decisions with no car present), Correct Rejections (Stop decisions with a car present), and advantageous decisions (Go decisions on trials with cues for low crash probability and Stop decisions on trials with cues for high crash probability). The effect of Social Exclusion was calculated as the change in behavioral measures between Social Exclusion and Peer conditions (i.e. Post > Pre Social Exclusion).

Cyberball. The Social Exclusion condition was effected using the Cyberball game (Williams, Cheung, & Choi, 2000) which creates the subjective experience of being excluded using a computerized ball-toss game played by the subject and two peers ostensibly connected via the Internet. The subject viewed three animated computer figures representing themselves (the subject) and two peers (which were portrayed to be the same two individuals throughout all aspects of the experiment) and played a virtual game involving tossing a ball among the three participants (for a total of 44 throws). Unbeknownst to the subject, the first round was programmed to alternate between brief periods in which throws were relatively equal or favored the subject, creating an inclusion experience alternating between fair play (approximately 1/3 of the throws) and overinclusion (during which the two peers always threw to the subject, and never to each other). The second round was programmed to alternate between brief periods in which throws were relatively equal or excluded the subject, creating an exclusion experience alternating between fair play and exclusion (during which the peers throw only to each other, and never to the subject). These brief alternating periods have been used in previous fMRI studies with adolescents (Bolling et al., 2011a, 2011b) and are better suited for an fMRI study while still retaining the ability to create a subjective experience of exclusion (or inclusion).

Task Sequence

See Figure 2 below for a visual depiction of the order in which tasks were presented in this protocol. Subjects were informed that they were to play several online games with two other same-age peers, one male and one female, who were in different locations (i.e., not local people that they may be more likely to know). In order to “meet” the other peers, the subjects recorded a brief video profile that consisted of the subject stating his or her name and an activity that they enjoy. Typical profile statements were “Hi, my name is Julie and I like to play volleyball. My friends would say I'm really athletic.” or “Hey, I’m Matt and I like skateboarding. My friends would say that I'm fun to hang out with.” Video recordings were then uploaded to a shared Internet file folder (Dropbox) while subjects watch. Subjects were told that each person would meet the other two by viewing their profiles. Subjects then received instructions and a demonstration of the two computer games (YLG and Cyberball).

After completing four rounds in which no peers were watching (two Practice rounds of YLG in the mock scanner and two Alone in the real MRI scanner), subjects were told that they would now interact with the two peers via

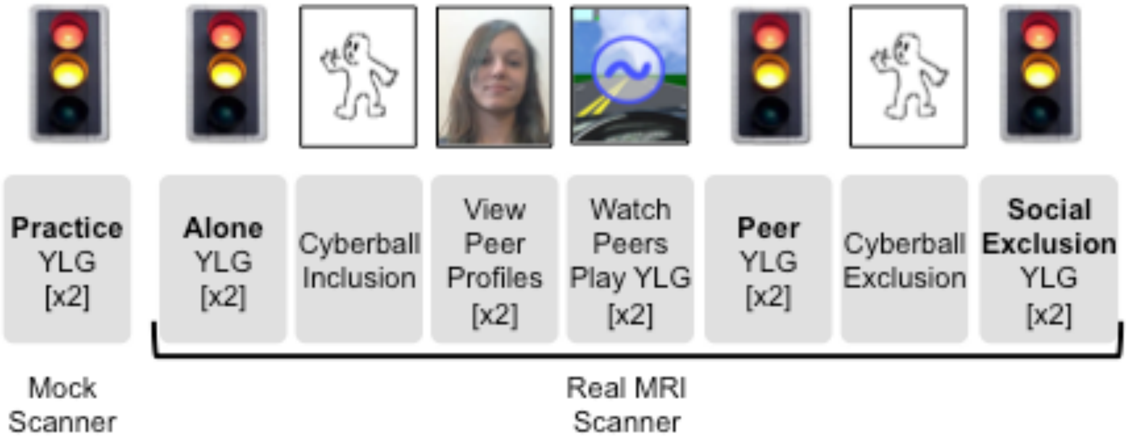

Figure 2. In the Yellow Light Game (YLG), participants have to decide to Go or Stop at each intersection. The goal is to reach the end of the course as quickly as possible. Choosing to Stop incurred a 2.5 second delay, while choosing to Go could result in no delay, or a 5.0 second delay in the event of a crash. Parameters were modified to create conditions that across each run yielded an expected value that was equal for Go and Stop, maximizing contributions of individual differences and social contextual effects. Participants played the YLG alone twice in the mock scanner, then two more times in the real scanner. Then social context manipulations were applied by playing Cyberball (Williams, Cheung, & Choi, 2000), viewing peer video profiles, and watching peers play the YLG. Participants played the YLG while ostensible peers (from the Cyberball game) watched them, twice after inclusion. and then twice after exclusion.

computer desktop sharing software connected over the Internet. All subjects then completed the inclusion round of the Cyberball game, and were subsequently told that each person would complete the YLG while the other two peers watched. Subjects then viewed the video profile and a recorded YLG round from each of the peers. To facilitate the cover story, the subject was asked to confirm that they could see and hear the remote connection of each peer and were required to wait to begin their session until similar confirmation was received from the remote peers. The driving behavior of the peers was programmed to represent average to slightly above average performance. One peer completed the course with average risk (number of go decisions) and average performance (number of crashes and course time), while the other peer completed the course with slightly above-average risk and performance. Both performance levels were selected based on pilot testing results to be within the normal range of participant performance. After viewing each of the remote peer sessions, the subject completed two rounds of the YLG while being watched by these same remote peers (Peer condition). Next, subjects completed the exclusion round of the Cyberball game with the same two peers. After completing this second round of Cyberball, subjects completed two final rounds of the YLG (Social Exclusion condition) and were told that the same peers were still watching their performance. Manipulation checks were conducted following the scanning procedure to assess whether subjects believed the manipulation. Of the 55 subjects in the final analyses, 47 (85.5%) responded that they believed the peer interaction was real, six (1.8%) indicated they “weren’t sure,” one (1.8%) explicitly expressed disbelief that they were interacting with real peers, and one (1.8%) declined to answer the question.

Primary Questionnaire Measures

Susceptibility to Social Influence. Trait differences in this construct were assessed with the Resistance to Peer Influence questionnaire (RPI) - a 10-item self-report scale, which measures the degree to which adolescents were influenced by the views and opinions of peers (Steinberg & Monahan, 2007). Items were scored on a scale of 1 to 4, with lower scores representing less resistance to peer influence (i.e., more susceptibility to the opinions of peers), and some items were reverse-coded. The total RPI score was the computed average of all item scores.

Affective Response to Social Exclusion. Individual differences in affective state following exclusion were assessed with the Need Threat Scale (NTS). The NTS is a 12-item self-report measure that assesses the extent to which social needs are satisfied, including items that measure subjects' feelings of reduced self-esteem, belongingness, social control, and meaningful existence (Williams et al., 2000). The total NTS score was the average of all item scores, with lower scores reflecting less social need satisfaction (i.e., more threat to social needs). Individual differences in trait-level sensitivity to social rejection were assessed with a modified version of the Rejection Sensitivity Questionnaire (RSQ; Downey & Feldman, 1996; Downey, Lebolt, Rincón, & Freitas, 1998), created for the current study by adapting items from the child and adult versions to be more relevant to an adolescent sample. The measure assesses angry and anxious expectations of rejection in 10 hypothetical situations commonly faced by adolescents.

Real-World Risk-Taking. Substance use, risky sexual behavior, and aggressive behavior were assessed by the self-reported Youth Risk Behavior Survey (YRBS; Eaton et al., 2012) which included items for whether the subject had ever engaged in a behavior and items for the number of times the subject engaged in the behavior in the last 30 days. Examples include smoking cigarettes, drinking alcohol, smoking marijuana, and having sex without a condom). Affiliation with deviant peers was assessed with the Risk Behavior and Deviant Peer Affiliation Scale (Metzler, 2001), and the rule-breaking and aggressive behavior was assessed using subscales from the parent reported CBCL (Achenbach & Rescorla, 2001). Risky driving behavior was assessed with the Driving Experiences Survey developed for this study.

Additional Questionnaire Measures

Additional trait-level measures related to impulsivity, sensation seeking, social experience, and general negative affect, as well as covariates such as intelligence, socioeconomic status, pubertal development, driving experience, and video game experience were also assessed.

Impulsivity. The Barratt Impulsivity Scale (BIS-15; Spinella, 2007) is a 15-item self-report short form of the BIS that measures overall impulsivity and subscales for nonplanning, motor impulsivity, and attention impulsivity. Additional subscales acquired to assess impulsivity included the premeditation and persistence subscales from Impulsive Behavior Scale (UPPS-P; Cyders et al., 2007), and the subscales for attention problems and thought problems from the parent-reported Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001).

Sensation Seeking. The Brief Sensation Seeking Scale (BSSS; Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002) is an 8-item self-report short form assessing the dispositional quality of sensation seeking with subscales for thrill and adventure seeking, disinhibition, experience seeking, and boredom susceptibility. Additional subscales acquired to assess sensation seeking included the sensitivity to reward subscale of the Sensitivity to Punishment and Sensitivity to Reward Questionnaire - Short Form (SPSRQ; Torrubia, Avila, Moltó, & Caseras, 2001), and the positive urgency and sensation-seeking subscales from the UPPS-P (Cyders et al., 2007).

Social Experiences. In addition to the RPI and NTS, measures of social experiences included the Revised Peer Experiences Questionnaire (PEQ-R; Prinstein, Boergers, & Vernberg, 2001), which assesses bullying and victimization; the Adverse Early Experiences Scale for Children (ACES-C; Felitti et al., 1998); and the parent-reported social problems subscale from the CBCL (Achenbach & Rescorla, 2001).

General Negative Affect. Measures of general negative affect included the Screen for Child Anxiety Related Disorders, Child Version (SCARED; Birmaher et al., 1997), the Center for Epidemiological Studies Depression Scale for Children (CED-DC; Weissman, Orvaschel, & Padian, 1980), and the withdrawn-depressed, anxious-depressed, and somatic complaints subscales from the parent-reported CBCL (Achenbach & Rescorla, 2001).

Covariates. Covariate measures included chronological age, intelligence, socioeconomic status, pubertal development, driving experience, and video game experience. The following measures were collected to assess these covariates: verbal and matrix reasoning subscales from the Wechsler Abbreviated Scale of Intelligence (WASI-II; Wechsler, 1999); parent reports of maternal and paternal education and household income; Pubertal Development Scale (PDS; Petersen, Crockett, Richards, & Boxer, 1988); as well as the Driving Experiences Survey and Video Game Survey (both developed for this study). Control variables demonstrating significant correlations with primary dependent variables will be entered as covariates in analyses. This is particularly important in the case of puberty, which represents an important theoretical component of neurobiological imbalance theories, as the sample spans several stages of pubertal development that may affect risky behavior.

***Behavioral and Questionnaire Data Analysis*.**

All behavioral and questionnaire data were inspected for outliers. Corrective transformations (e.g., Windsorizing) were performed as needed. Individual subject item scores above three standard deviations (sd) from the mean in either direction were replaced by the value at three standard deviations from the mean and tests were recomputed. If the test results changed significantly, the original and the Windsorized results are reported. Given the age range of the sample, the distributions of real-world risk-taking measures were strongly positively skewed.

MRI

MRI Data Acquisition. MRI data were acquired on a 3.0 Tesla Siemens Skyra scanner with 20 channel head coil (Siemens, Erlangen, Germany) at the Robert and Beverly Lewis Center for NeuroImaging at the University of Oregon. Blood oxygen-level dependent, echo-planar images (BOLD-EPI) were acquired with T2*-weighted gradient echo sequence (TE = 27 ms, TR = 2000 ms, flip angle = 90°, multiband slice accelerate factor = 3, GRAPPA integrated parallel acquisition technique (iPAT) = 2 (, 100 × 100 voxel matrix 200 mm field of view, bandwidth = 1785 Hz/pixel, 72 contiguous axial slices with interleaved acquisition, slice thickness = 2 mm, and in-plane resolution of 2 × 2 mm). The first 2 scans were discarded to allow scanner magnetization to reach equilibrium.

High-resolution structural scans were acquired using an inversion recovery T1-weighted 3D MP-RAGE pulse sequence (TE = 3.41 ms, TR = 2500 ms, TI = 1100 ms, flip angle = 7°, multiband slice accelerate factor = 3, GRAPPA (iPAT) = 2, 256 x 256 voxel matrix, 256 x 192 rectangular field of view, bandwidth = 130 Hz/pixel, 176 contiguous axial slices coplanar to the functional scans, slice thickness = 1 mm, and in-plane resolution of 1 x 1 mm). Prior to each run, field map scans were acquired to obtain magnetization values used to correct for field inhomogeneity (TE[1] = 4.37 ms, TE[2] = 6.83 ms, TR = 639 ms, flip angle = 60°, 100 × 100 voxel matrix, 200 mm field of view, bandwidth = 1530 Hz/pixel, 72 contiguous axial slices with interleaved acquisition, slice thickness = 2 mm, and in-plane resolution of 2 × 2 mm). Computer images for the tasks were projected from an LCD display onto a mirror above the subject's eyes. Behavioral responses were acquired using a button box interfaced with task software. Volume-to-volume motion was calculated from using mean translation and rotation movement across participants was less than .01 mm for the Peer and Social Exclusion conditions (range: .005 to .007 mm) in any dimension and did not differ between conditions (paired sample t-test p-values all greater than .4). Participants with maximum translation or rotation movement of 2 mm or more were excluded (three subjects). Average maximum translation and rotation movement did not differ between conditions (all p-values greater than .2). One subject was excluded for having insufficient number of Go decisions.

MRI Data Analysis**.** DICOM images were converted to NIfTI format via MRIConvert (http://lcni.uoregon.edu/~jolinda/MRIConvert/). Imaging data were analyzed using SPM12 (www.fil.ion.ucl.ac.uk/spm). The first six functional image volumes from each run were discarded to allow for T1 equilibrium effects. Preprocessing included rigid-body transformation (realignment) and coregistration to the first functional image of each run, and the first image of each run was subsequently coregistered to the first image of the first functional run. Voxel displacement maps were used to correct for field inhomogeneities. Anatomical images were manually reoriented to the AC-PC line and the resulting transformations were applied to all functional images. Anatomical images were segmented into six tissue types using the unified segmentation approach (Ashburner, 2007). DARTEL was used to create a group anatomical template, transformations from which were applied to stereotactically normalize functional images to the standard ICBM-152 template supplied with SPM12 (, 2007). Normalized data were smoothed using a 6 mm FWHM Gaussian kernel. Fixed-effects models were analyzed in SPM12 using the canonical HRF basis function with no derivatives. An explicit mask for each subject was created by combining optimum threshold masks from the mean functional image and the gray matter and white matter tissue class images (rc1 and rc2) from DARTEL. The time series for each participant were high-pass filtered at 128 seconds to remove low-frequency drifts.

Fixed-effects analyses used a general linear model (GLM) created with eight regressors of interest, modeled as zero duration events: four decision regressors (Go-No Car, Go-Crash, Stop-No Car, Stop-Car,) and five outcome regressors (Safe, Crash, False Alarm, Correct Rejection, Penalty, and GameOver; see Figure 2). The yellow light preceding a given decision (Stop or Go) served as the onset for all decision regressors. The Stop-No Car event corresponded to trials in which the subject chose to stop for the traffic light and no cross car was present. In these trials the outcome regressor was modeled on the visual symbol (a blue circle with tilde character) that displayed at the same time a car would have crossed in front of the participant if a cross car were present on the trial. The Stop-Car event corresponded to trials in which the subject chose to stop for the traffic light and a cross car was present. In these trials the outcome regressor was modeled on the visual appearance of the cross car in front of the participant. The Safe-Go event corresponded to trials in which the subject chose to go and no cross car was present (i.e. there was no crash). In these trials the outcome regressor was modeled on the appearance of a visual "No Car" symbol (a blue circle with tilde character) that displayed at the same time a crash would have happened if a cross car had been present. The onset of the outcome of the Go-Crash event corresponded to the moment of the cross car crashing into the participant’s car. The Penalty event corresponded to trials in which the participant failed to make a decision before their car reached the intersection. In these trials, the outcome regressor was modeled on the visual appearance of a "Penalty" symbol (a red circle with an "X" in the center). An additional regressor was modeled on the appearance of the Game Over graphic, which displayed the participant's time and number of crashes for the round of intersections. The present analysis reports only the results from the decision regressors; outcome regressors will not be discussed further.

Parameter estimates resulting from the GLM were used to create linear contrast images for each of the nine event conditions against an implicit baseline during which participants were “driving”, but not making any decisions or receiving any feedback, representing a high-level control condition. These fixed-effects contrast images were then entered into random-effects analyses. Monte Carlo simulations were conducted using AlphaSim (3dClustSim) to determine the minimum cluster size needed for a familywise error (FWE) rate of .05. Results indicated a cluster extent threshold of k = 44 voxels at a voxelwise threshold of p = .0001, uncorrected.

MarsBaR (http://marsbar.sourceforge.net/) was used to create four regions of interest (ROIs) to examine differences in BOLD signal across different conditions and to conduct regression tests with behavioral measures. Bilateral ROIs were created by defining a 12 mm spherical mask centered on the peak coordinates of functionally-derived striatal clusters in the contrast of Go decisions greater than Stop decisions in the Alone condition (Figure 5A; left: -18 4 -10; right 14 4 -10). These ROIs were then used to extract parameter estimates striatal activity during decisions in the Peer and Exclusion conditions. This approach was adopted to obtain an ROI that was not dependent on the contrasts and conditions in the primary analyses of the Peer and Social Exclusion conditions. An ROI for SMA (also referred to as juxtapositional lobule cortex) was created and used to examine the effects of condition on regions associated with response execution or inhibition (Duann et al., 2009) and selection of action sets (Rushworth et al., 2005). An anatomical ROI of the supplementary motor area (SMA; also known as juxtapositional lobule cortex) was created from the Harvard-Oxford cortical atlas (Caviness et al., 1996; Desikan, 2006) with center of mass coordinates: 0, -2, 58. This ROI encompasses the bilateral part of Brodmann Area 6 situated on the medial wall, including subareas referred to as supplementary motor area (SMA) and posterior presupplementary motor area (preSMA) extending anteriorly to y = 18 (Zhang et al., 2012). Two separate ROIs were created for anterior and posterior temporoparietal junction (TPJ) using masks developed by Mars et al. (2012) through a two-step process of diffusion-weighted imaging tractographybased parcellation in conjunction with resting state connectivity with center of mass coordinates of 58, -37, 20, and 54, -55, 26, respectively.

CHAPTER III

RESULTS

Behavioral Results

Effects of Condition. Behavioral results were defined as the percentage of Go and Stop decisions for the 40 Stoplight trials completed by participants in each condition (Practice, Alone, Peer, and Social Exclusion). Average rates of Go decisions ranged from 38% to 42% (Figure 3A), which is below the optimal rate of 50% given the average crash probability of .50. A linear effect of condition was found for Go decisions, F(1,54) = 5.69, p=.02, partial η^2_p sq = .10, indicating that Go decisions increased across conditions, despite an initial non-significant decrease from Practice to Alone runs. Relatedly, average rates of Stop decisions ranged from 54% to 59% (Figure 3B). The percent of Stop decisions was lower in the Practice condition than in the Alone condition, t(54) = 2.58, p = .01. A quadratic effect of condition was found for Stop decisions, F(1,54) = 8.64, p<.01, η^2_p = .14, showing that Stop decisions increased in the Alone and Peer conditions relative to the Practice condition, then decreased in the Social Exclusion condition. Finally, a linear effect of condition was found for average Game Time, F(1,54) = 15.74, p<.001, η^2_p = .23, showing that game performance improved significantly across conditions (Figure 3C). Although participants trended towards better times with each successive condition, Game Times did not differ significantly between Alone and Peer conditions, p=.053) or between Peer and Social Exclusion conditions (p > .80) after Bonferroni correction,

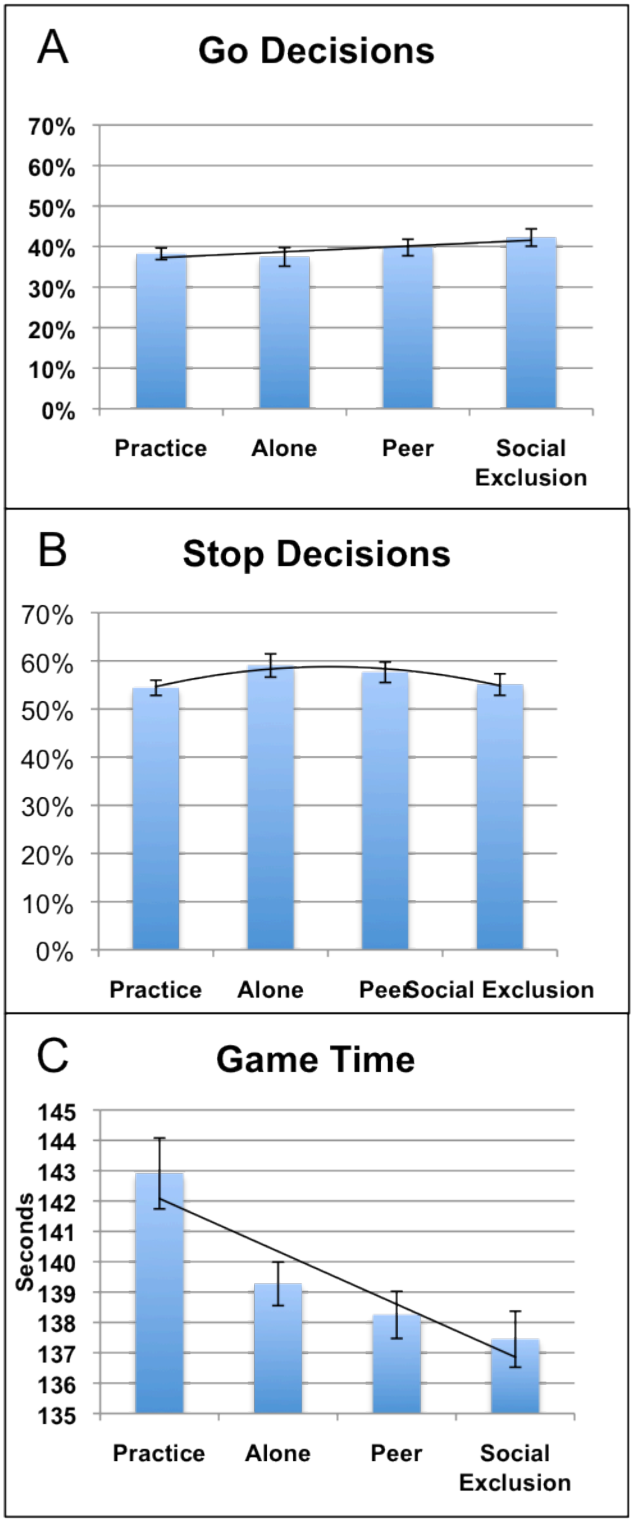

Figure 3. Panels A and B. Percentage of Go and Stop decisions across conditions. Panel C. Game performance across conditions.

although they did differ between Practice and Alone conditions, p = .04. Taken together, these behavioral results suggest that participants learned the game rather rapidly during the Practice condition, and that any observed changes in neural activity across conditions are not likely due to gross differences in behavioral performance.

***Individual Differences*.** Change in Go decisions from the Alone condition to the Peer condition was not significantly related to RPI (r(53) = -.21, p = .13) until controlling for PDS (r(53) = -.27, p = .04). PDS was weakly, but negatively related to RPI (r(53) = -.09, ns), and exerted a suppression effect on the association between RPI and change in Go decisions. In other words, after accounting for differences in pubertal development, teens with *less* resistance to peer influence *increased* Go decisions when peers were watching. RPI also predicted a change in Go decisions following Social Exclusion (r(53) = .29, p = .03; see Figure 4A)), but the effect reversed directions, indicating that adolescents with lower resistance to peers now *decreased* their Go decisions following Social Exclusion. This effect held, and in fact was stronger, after controlling for pubertal status (r(53) = .34, p = .01), indicating that the influence of peers was again higher after accounting for differences in maturation indexed by puberty. The effect also remained significant after individually controlling for age, gender, IQ, and maternal education (all p values <= .03). As expected given the nearly inverse relationship between Go and Stop decisions, lower RPI also predicted increased Stop decisions after Social Exclusion, r(53) = -.30, p=.03 (not

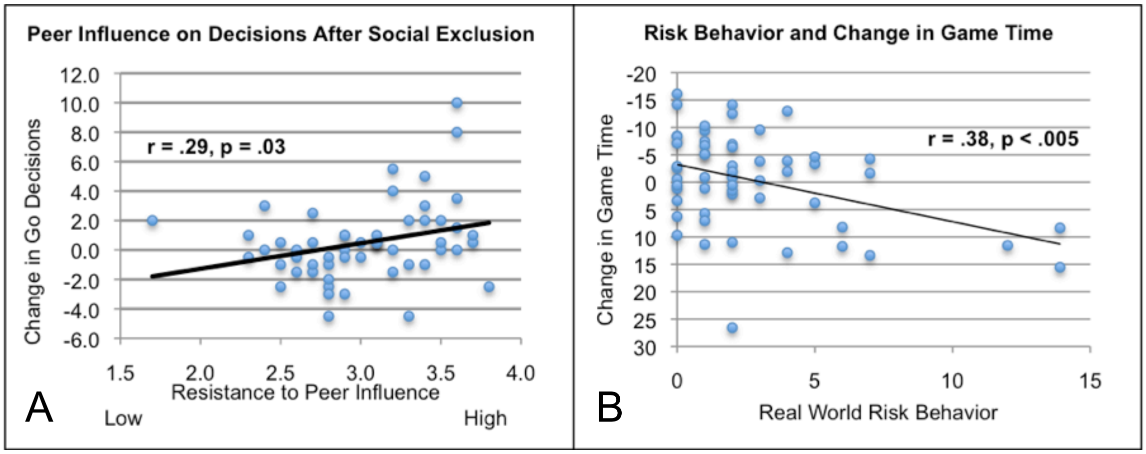

Figure 4. Panel A. Adolescents with low resistance to peer influence decreased risk taking after social exclusion. Panel B. Subjects with higher real world risk behavior decreased Go decisions after social exclusion.

shown). There was a trend level relationship between RPI and change in Game Time after social exclusion (r(53) = -.23, p = .09) that attained significance after controlling for pubertal status (r(53) = -.30, p = .03). Despite choosing to Go more often, adolescents with *less* resistance to peers performed *worse* on the game following Social Exclusion as measured by higher Game Time in seconds. Real World Risk (RWR) behavior did not predict changes in Go decisions in Peer or Social Exclusion conditions, but did predict changes in Game Time after Social Exclusion (r(53) = .38, p < .005). Adolescents with *greater* self-reported engagement in substance use, risky sexual behavior, and aggressive and delinquent behavior performed *worse* on the game following social exclusion (Figure 4B). This effect remained significant after individually controlling for age, pubertal status, gender, IQ, and maternal education (all p-values < .05).

Neuroimaging Results

***Effects of Task*.** To examine neural patterns associated with performing the Yellow Light Game prior to assessing the effects of social context, imaging results were collapsed across Peer and Social Exclusion conditions (the Alone condition was excluded because peers were not watching those rounds of the YLG). The contrast of Go decisions with Stop decisions showed expected activity in regions common to other decision-making studies: striatal areas, including caudate and lentiform nucleus (i.e. putamen and globus pallidus), insula, and strong activity in motor, visual, and auditory areas (sensorimotor cortex, supplementary motor area, superior parietal, cerebellar, as well as occipital and lateral temporal cortex; see Table 1 for full list of coordinates and cluster sizes).

Table 1. Go Decisions > Stop Decisions Across Peer and Social Exclusion Conditions

			MNI		
Area	*t*	*k*	x	y	z
Go Decisions > Stop Decisions					
L Postcentral Gyrus	14.68	342	-37	-29	50
L Cingulate Gyrus	10.65	*	-7	-2	49
L Medial Frontal Gyrus	9.84	*	-5	-12	52
R Lentiform Nucleus	9.28	453	14	3	-4
L Lentiform Nucleus	8.19	372	-16	5	-3
L Caudate	7.44	*	-10	4	4
L Thalamus	7.21	463	-7	-20	-1
R Thalamus	6.16	*	6	-19	6

Red Nucleus	6.05	*	3	-18	-5
L Precentral Gyrus	6.15	65	-51	-1	36
R Precentral Gyrus	5.85	74	30	-16	55
R Postcentral Gyrus	5.68	33	48	-21	41
L Insula	5.02	8	-40	-4	14
L Insula	4.95	10	-34	11	12
L Claustrum	4.94	*	-31	11	14

			MNI		
Area	*t*	*k*	x	y	z
Stop Decisions > Go Decisions					
Cerebellum	7.74	367	6	-72	-4
L Cuneus	7.26	*	4	-86	24
R Lingual Gyrus	7.26	*	8	-80	-4
L Superior Occipital Gyrus	7.25	*	-12	-98	24
L Fusiform Gyrus	7.02	*	-26	-76	-10
L Superior Temporal Gyrus	6.59	249	-58	-20	10
R Middle Temporal Gyrus	5.68	91	54	-66	18
R Superior Temporal Gyrus	5.65	95	56	-14	6
L Temporoparietal Junction	5.31	99	-50	-54	28
R Middle Occipital Gyrus	-5.27	14	30	-92	18
R Precuneus	-5.26	17	10	-52	70
L Fusiform Gyrus	-5.15	20	-28	-56	-8
R Supramarginal Gyrus	-4.81	6	64	-44	12

Note. MNI = Montreal Neurological Institute; x, y, and z refer to the left-right, anterior-posterior, and superior-inferior dimensions, respectively; t refers to the t statistic at those coordinates (local maxima or submaxima); k refers to cluster extent in voxels (2x2x2 mm); R = right, L = left; * = local maxima. Results shown at p < .05, FWE corrected.

Effects of Condition. To assess the specific effects of the Peer and Social Exclusion conditions, analyses were conducted in several stages. Contrasts of Go decisions with Stop decisions were first examined *within* each condition separately (e.g. Go decisions in the Peer condition compared to Stop decisions in the Peer condition), followed by contrasts of decisions *between* conditions (e.g. Go decisions in the Peer condition compared to Go decisions in the Social Exclusion condition). Subsequently, ROI and mediation analyses were conducted to provide a more comprehensive understanding of specific effects.

Contrasts within each condition revealed similarities in each decision type in additions to some differences (Table 2). Go decisions compared to Stop decisions showed greater activity in reward, motor, and attention regions in both Peer and Social Exclusion conditions. Stop decisions compared with Go decisions exhibited greater activity in occipital, cerebellar, and temporal regions. Striatal activity appeared greater during Go decisions in the Peer condition than in the Social Exclusion condition. Interestingly, Stop decisions in the Peer condition were associated with greater activity in left temporoparietal junction whereas similar activity was not found in the Social Exclusion condition, although a smaller cluster was found in the latter condition in right temporoparietal junction (TPJ).

Table 2. Decisions Within Conditions

			MNI		
Area	*t*	*k*	x	y	z
Go Decisions > Stop Decisions in Peer Condition					
L Postcentral Gyrus	12.33	488	-38	-24	54
L Medial Frontal Gyrus	9.26	*	-4	4	50
L Superior Frontal Gyrus	7.60	*	-6	-8	66
L Precentral Gyrus	7.23	*	-16	-16	68
R Lentiform Nucleus	9.71	814	16	4	-10
R Caudate	6.80	*	10	4	8
L Lentiform Nucleus	7.94	165	-16	8	-6
L Red Nucleus	7.43	*	-4	-20	-8
L Thalamus	7.37	*	-6	-22	-2
L Caudate	6.83	*	-10	4	8
L Insula Lobe	5.49	125	-30	22	6
R Postcentral Gyrus	5.40	84	54	-16	42
R Precentral Gyrus	5.17	119	42	-4	46
R Middle Frontal Gyrus	3.99	*	38	-10	58

			MNI		
Area	*t*	*k*	x	y	z
Stop Decisions > Go Decisions in Peer Condition					
L Superior Occipital Gyrus	6.89	643	-12	-96	24
L Calcarine Gyrus	6.80	*	0	-94	16
R Lingual Gyrus	6.77	*	8	-78	-4
L Cuneus	6.73	*	2	-88	24
R Cuneus	6.73	*	10	-90	24
L Temporoparietal Junction	5.91	581	-48	-62	32

L Middle Occipital Gyrus	4.51	*	-46	-74	22
L Superior Temporal Gyrus	4.48	*	-40	-54	30
R Superior Temporal Gyrus	5.12	144	56	-16	6
R Insula Lobe	3.94	*	46	-12	4
Posterior Cingulate	5.05	58	0	-42	8
L Middle Temporal Gyrus	4.63	149	-50	-24	6
L Superior Temporal Gyrus	4.61	*	-56	-8	4
R Precuneus	4.49	72	8	-54	68
R Middle Temporal Gyrus	4.39	82	44	-70	16

Go Decisions > Stop Decisions in Social Exclusion Condition

L Postcentral Gyrus	10.27	140	-38	-26	54
L Precentral Gyrus	6.27	*	-32	-16	66
L Inferior Parietal Lobule	5.14	*	-48	-26	48
L Cingulate Gyrus	7.39	935	-6	2	50
L Medial Frontal Gyrus	6.79	*	-4	-6	58
R Medial Frontal Gyrus	5.62	*	8	6	54
L Anterior Cingulate	4.99	*	-10	18	36
L Medial Frontal Gyrus	4.11	*	-10	0	66
R Caudate	5.31	150	12	6	-4
R Lentiform Nucleus	4.99	*	14	4	-10
R Middle Frontal Gyrus	5.30	59	34	-10	58
L Lentiform Nucleus	5.21	124	-14	6	-8
L Caudate	4.82	*	-8	6	2
Thalamus	5.11	220	6	-18	6
Red Nucleus	4.41	48	6	-28	-6
Thalamus	4.37	*	-4	-28	-4

Stop Decisions > Go Decisions in Social Exclusion Condition					
L Superior Temporal Gyrus	5.99	354	-58	-20	10
L Heschls Gyrus	4.33	*	-38	-32	14
R Cerebellum	5.74	737	8	-70	-4
L Calcarine Gyrus	5.48	*	-2	-92	0
R Lingual Gyrus	4.78	*	12	-74	8
L Fusiform Gyrus	5.22	310	-30	-76	-12
L Cerebellum	4.89	*	-22	-78	-16
L Lingual Gyrus	3.89	*	-12	-82	-8
R Cuneus	4.73	246	4	-86	22
L Calcarine Gyrus	4.62	*	-4	-82	14
R Temporoparietal Junction.	4.70	112	52	-66	20
R Superior Temporal Gyrus	4.66	70	68	-16	12

Note. MNI = Montreal Neurological Institute; x, y, and z refer to the left-right, anterior-posterior, and superior-inferior dimensions, respectively; t refers to the t statistic at those coordinates (local maxima or submaxima); k refers to cluster extent in voxels (2x2x2 mm); R = right, L = left; * = local maxima. Results shown at p-threshold of .0001 with cluster extent threshold of 44 voxels, which achieves FWE correction at $p < .05$.

Contrasts of decisions *between* conditions revealed activity differences primarily in the comparison of Go decisions in the Peer condition to Go decisions in the Social Exclusion condition (Table 3). Of primary interest, Go decisions in the Peer condition relative to Social Exclusion condition were associated with greater activity in the caudate (Figure 5), as well as in motor areas. Some additional differences were found in the other comparisons between conditions, however none of these effects survived correction for multiple comparisons.

Table 3. Contrasts of Decisions Between Conditions

			MNI		
Area	*t*	*k*	x	y	z
Go Decisions Peer Condition > Go Decisions Social Exclusion					
L Caudate	57	4.86	-12	0	12
L Superior Frontal Gyrus	85	4.62	-20	-8	68
L Medial Frontal Gyrus	128	4.43	-2	-6	68
R Superior Frontal Gyrus	71	4.30	28	-4	64

Note. MNI = Montreal Neurological Institute; x, y, and z refer to the left-right, anterior-posterior, and superior-inferior dimensions, respectively; t refers to the t statistic at those coordinates (local maxima or submaxima); k refers to cluster extent in voxels (2x2x2 mm); R = right, L = left; * = local maxima. Results shown at p-threshold of .0001 with cluster extent threshold of 44 voxels, which achieves FWE correction at $p < .05$

Comparison of parameter estimates for the striatal clusters (FIgure 6 A) between conditions showed that, as expected, activity was greater for Go decisions than for Stop decisions, $t(54) = 6.96$, $p < .001$ (Figure 6 B). Within Go decisions, striatal activity was significantly less in the Social Exclusion condition compared

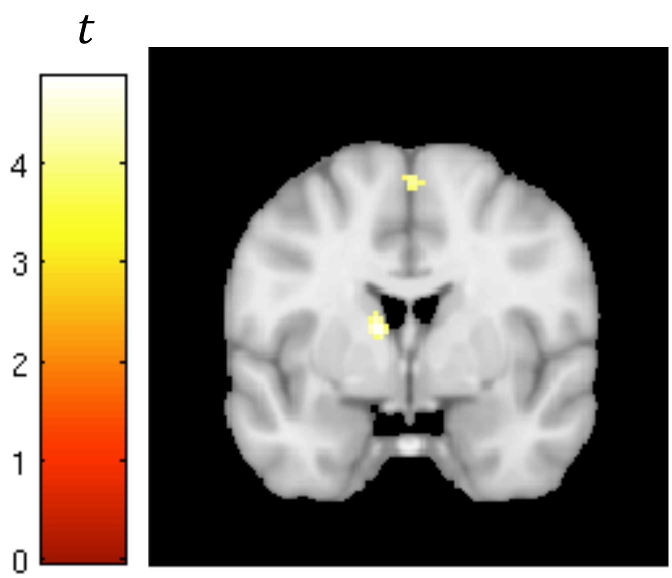

Figure 5. Dorsal caudate was significantly less active during Social Exclusion than in the Peer condition (p < .0001, k > 44; y = 0).

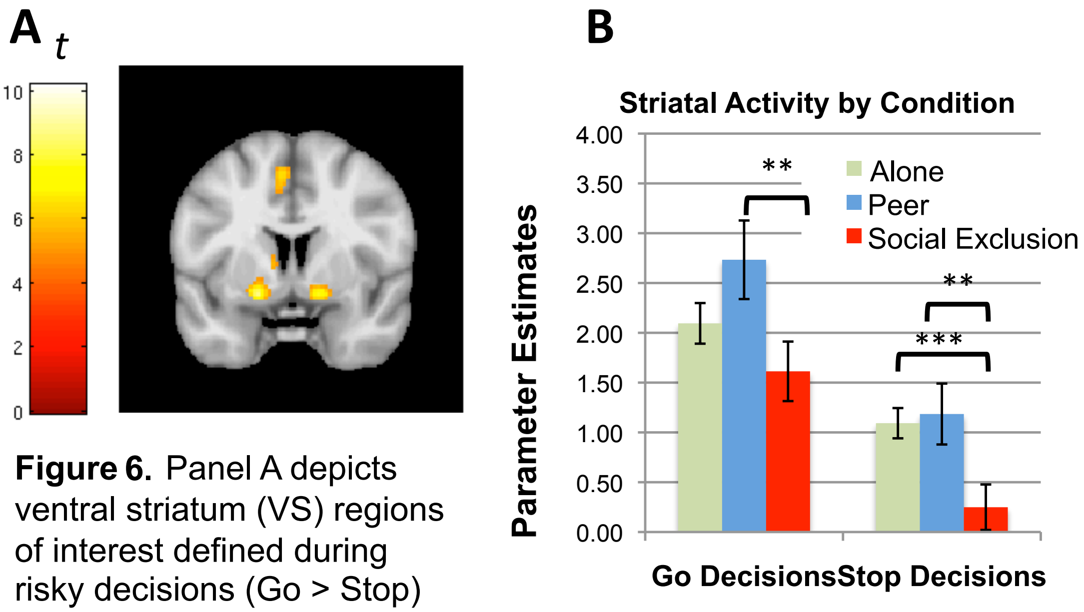

Figure 6. Panel A depicts ventral striatum (VS) regions of interest defined during risky decisions (Go > Stop) in the Alone condition (p < .05 FWE corrected; y = 4). Panel B depicts VS activity across all three conditions.

with the Peer condition, t(52) = 2.85, p = .006, but was not different between the Alone and Peer or Alone and Social Exclusion conditions (p-values > .10). Thus, activity in this reward region decreased after being excluded by peers, despite an overall increase in behavioral Go decisions from Peer to Social Exclusion.

Individual Differences. Regression tests of RPI on whole brain contrasts of Go compared to Stop decisions within the Peer or Social Exclusion conditions, as well as in contrasts between the conditions, revealed no clusters that survived correction. ROI analyses were conducted for the two main behavioral outcomes associated with individual differences reported above (i.e. the association of RPI with increased Go decisions and the association of RWR with game performance) for each of the four regions: ventral striatum (VS), supplementary motor area (SMA), and anterior and posterior temporoparietal junction (TPJ). Higher RPI was predictive of increased BOLD signal parameter estimate from the Peer to Social Exclusion condition in the SMA region of interest, r(53) = .34, p = .01), but not in VS or either TPJ ROI (all p values > .25). Mediation tests indicated that the indirect effect of RPI on the change in Go decisions after social exclusion was not significantly mediated by change in SMA activity (p > .50, bias-corrected confidence intervals of the effect: -.24 and .71). Higher RWR was associated with decreased activity in the ventral striatal ROI, r(53) = -.27, p = .04, but not with activity in SMA or either TPJ ROI (all p values > .25), revealing that adolescents with higher levels of real world risky behavior (comprised of drinking, smoking, marijuana, and other drug use, along with aggression and risky sexual behavior) showed a drop in striatal activity following Social Exclusion. Mediation tests showed that the indirect effect of RWR on change in game performance was not mediated by activity change in VS ($p > .25$).

CHAPTER IV

DISCUSSION

This dissertation examined the effects of changes in social context on adolescent decision making and individual differences in those effects. It was designed based on the premise that adolescent decisions are strongly influenced by the situation in which the decision is made, traits specific to the teen, and the interaction between the two. After being excluded by peers, adolescents with greater susceptibility to peer influence made fewer Go decisions than in the previous (Peer) condition. Teens with higher rates of RWR exhibited a drop in performance following social exclusion. Neuroimaging results showed that, after the event of social exclusion, adolescents as a group showed decreased activity in striatum, a region often indicated in studies of motivation and reward. The drop in striatal activation was strongest for teens with higher rates of RWR. To interpret these results, behavioral and neuroimaging findings are each discussed in order of 1) the effects of the task, 2) the effects of the conditions, and 3) individual differences in response to the conditions.

Behavioral Results

The behavioral results showed that the task was an effective method of capturing variance in decision making. The sharp improvement in performance (faster Game Times) from the Practice to Alone condition, coupled with nonsignificant changes in subsequent conditions, illustrates that subjects learned the basics of the game in a few rounds, establishing a baseline from which to assess changes associated with different social contexts. The finding that reaction time for decisions was not different between the Peer and Social Exclusion conditions suggests that the behavioral differences were not due to fatigue or repetition effects which would be suspected if reaction times were markedly slower or faster, respectively. Performance scores were also not different between the Peer and Social Exclusion conditions which further supports the assertion that fatigue was not a significant influence on results (Langner, Steinborn, Chatterjee, Sturm, & Willmes, 2010). On average, subjects less often chose the option with greater variability (i.e. a Go decision) than would be ideal given the probability of crashing at .50. This is consistent with previous findings from other decision tasks in behavioral economics in which subjects exhibit risk-averse behavior (Kahneman & Tversky, 1979; Reyna & Farley, 2006). In addition, the decision results suggest that subjects were able to progress from a state of initial ambiguity for outcomes to a working estimate of the probability of outcomes within the first two rounds of the game, similar to the progression seen in other ambiguous decision tasks such as the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994; Brand, Labudda, & Markowitsch, 2006; Overman et al., 2004; Tymula et al., 2012).

The behavioral effects of condition indicated no significant increase in Go decisions from the Alone to the Peer condition or from the Peer to the Social Exclusion condition for the group as a whole. When considered in light of the wide range of differences in decision responses within the group, this lack of differences associated with changes in social condition suggest that not all adolescents in the sample responded in the same manner to the manipulations. This points to the need to examine more specific factors to predict which teens responded to Peer and Social Exclusion contexts, and how.

The effects of individual differences, in combination with changes in social context, provided a more informative view of adolescent decisions. In the Peer condition, the trend of lower RPI predicting increased Go decisions compared to the Alone condition supports previous findings that teens can make more risky decision when they believe they are being watched by peers (Cavalca et al., 2013; Gardner & Steinberg, 2005; O'Brien et al., 2011; Simons-Morton et al., 2005). It is notable that the associations between RPI and Go decisions and RPI and game performance became stronger after controlling for pubertal status. Although pubertal status was predictably correlated with age and RPI has been found to mostly increase linearly with age (Monahan, Steinberg, & Cauffman, 2009), in the current sample RPI was slightly negatively associated with pubertal status. On a scale of 1 (prepubertal) to 4 (postpubertal), subject scores on the Pubertal Development Scale (Petersen et al., 1988) ranged from 1.4 to 4.0 (M = 2.80, Mdn = 2.6) indicating that subjects in mid to late puberty had, on average, lower resistance to peers than subjects in pre or early puberty. Although this makes intuitive sense, given the increased importance of peer interactions as puberty progresses (Nelson, Leibenluft, McClure, & Pine, 2005), it is somewhat inconsistent with other findings regarding RPI and age. Broadly, however, the results suggest that the presence of peers was slightly to moderately predictive of increased Go decisions and better performance (faster Game Times) *specifically* for teens who reported being more susceptible to peer influence. However, the finding that increased Go decisions also resulted in improved game performance (in this case), provides an example that choosing the option with greater "risk" can also represent adaptive behavior with positive outcomes.

Individual differences were also found to be influential in the Social Exclusion condition, although in the opposite direction. After being excluded in the ball-throwing game by peers, subjects with low RPI decreased their Go decisions and subsequently performed substantially worse on the game. In addition, RWR also predicted worse performance on the game after exclusion. There are several possible interpretations of these findings. Subjects with greater susceptibility to peers could have experienced a rapid decrease in motivation to succeed at the game following their exclusion. Recall that the YLG in the Social Exclusion condition was played while subjects were ostensibly being watched by the same peers who excluded them. This could result in diminished reward salience for game performance. Another possible interpretation is that some subjects experienced negative affect following exclusion which could have the effect of increased cognitive load. In this view, cognitive resources occupied with emotional processing or emotion regulation would become unavailable for attention and error monitoring (Eysenck, Derakshan, Santos, & Calvo, 2007; Starcke & Brand, 2012; van den Bos, Harteveld, & Stoop, 2009). The fact that reaction times for decisions in the Peer and Social Exclusion conditions did not significantly differ somewhat reduces the plausibility of this interpretation, however. If the behavioral differences were due to increased cognitive load (affective or otherwise), decision reaction times should have been slower in the Social Exclusion condition. One other possible interpretation is that subjects low in resistance to peer influence consciously adopted a different strategy following social exclusion wherein they attempted to do better at the game by stopping more and choosing to go less. Regardless, the end result of this strategy was worse performance on the game and, as such, it represents a pattern of maladaptive decision making following exclusion, similar to the more implicit cognitive and affective interpretations described above.

Neuroimaging Results

The preceding discussion of possible interpretations highlights the difficulty of attributing behavioral outcomes to cognitive, affective, or purely discretionary causes. The use of neuroimaging provides an additional dimension by which to examine task, condition, and individual difference outcomes in order to gain a more complete understanding of the mechanisms of adolescent decisions. The results of the whole brain analysis of contrasts between Go and Stop decisions collapsed across conditions identify the primary regions involved in the task. These include areas associated with the key cognitive functions of attention to visual and auditory stimuli, motor control, and response selection as well as for areas commonly found in studies of decision making, reward, and learning. These networks are largely replicated in the contrasts between Go and Stop decisions within each condition; those results were reported separately to characterize the profiles of activation within each condition for use in future research and meta-analyses.

However, an interesting regional difference was observed in TPJ when querying within each condition that was not expressed when collapsing across conditions. The TPJ is frequently implicated in studies of social cognition (Saxe & Kanwisher, 2003; Van Overwalle & Baetens, 2009), including mentalizing (i.e. thinking about what other people are thinking), but also in studies of attention (Hutchinson, Uncapher, & Wagner, 2009; Mitchell, 2008), sensory salience (Corbetta, Patel, & Shulman, 2008), and episodic memory retrieval (Uncapher & Wagner, 2009; Wagner, Shannon, Kahn, & Buckner, 2005). The contrast of Stop decisions with Go decisions in the Peer condition revealed activation in left TPJ and posterior superior temporal sulcus, while the same contrast in the Social Exclusion showed activation in right TPJ. This reversal of laterality is notable because TPJ activation in studies of mentalizing has been found somewhat more often in the right hemisphere (Saxe, 2004) raising the possibility that the activation is related to the social exclusion manipulation. It should be emphasized, however, that due to statistical corrections for multiple comparisons, qualitative differences between two within-condition contrasts are not a reliable gauge of differences in one between-condition contrast. That is, for each condition, the contralateral TPJ may have been active as well, but did not exceed the threshold for statistical significance.

Of the four between-condition contrasts, only the comparison of Go decisions between the Peer and Social Exclusion conditions resulted in activation above threshold. The key result of interest from that contrast was in the striatum (specifically, the caudate nucleus). The striatum is implicated in a wide range processes including motivation, reward, and reinforcement learning (Dayan & Balleine, 2002; Diekhof, Kaps, Falkai, & Gruber, 2012), all of which are particularly relevant to the current inquiry into adolescent decision making. Due to the nature of this contrast as an interaction, the cluster could represent increased striatal activation in the Peer condition or decreased striatal activation during the Social Exclusion condition. Although both conditions represent social contexts, the Peer decision is largely a positive (or at least neutral) context that creates an environment of peer influence (as the peers observe the subject playing) and social comparison (when the subject plays after seeing the peers play). Previous studies have found increased striatal activation when subjects were observed by peers during a task (Simon, Becker, Mothes-Lasch, Miltner, & Straube, 2014), and when subjects received different rewards than a peer during a task (Bault, Joffily, Rustichini, & Coricelli, 2011; Fliessbach et al., 2007). In a highly relevant study, Chein and colleagues (Chein et al., 2011) found that striatal activity increased in adolescents, relative to adults, when being observed by peers while making risk decisions in a driving task. In contrast, the Social Exclusion condition is primarily a negative social context that creates a temporary negative affective state (Williams et al., 2000). To the best of our knowledge, no previous studies have found activation decreases in the striatum related to social exclusion or to negative affective states, although recent studies have provided evidence that striatal areas, including the nucleus accumbens (NAcc), are involved in active avoidance of aversive stimuli (Levita, Hoskin, & Champi, 2012).

To further explore the underlying basis of the striatal activation difference, bilateral striatum ROIs were created from the contrast of Go with Stop decisions in the Alone condition. This approach was designed to create a baseline of striatal activation from an independent condition with no social manipulation in order to assess changes in striatal activity related to the social contexts. The results show a clear drop in striatal activation from the Peer to the Social Exclusion condition for both Go decisions and Stop decisions. The fact that the proportion of Go and Stop decisions did not significantly differ between Peer and Social Exclusion conditions suggests that the drop in activity is not directly related to behavioral differences. Additionally, the pattern of striatal response across all three conditions (a non-significant increase from the Alone to Peer condition, then a significant decrease in the Social Exclusion condition; i.e. a nonlinear pattern of change), strongly suggests that the decrease is not driven by a repetition suppression effect (i.e. where repeated engagement in a task results in linear decrease in activation of an involved area; (Grill-Spector, Henson, & Martin, 2006).

Although the ROI analyses showed that striatal response decreased for adolescents as a group, the results of individual difference tests of ROI activation did not present a definitive indication of which of the underlying processes were involved in the behavioral change. While low RPI was predictive of decreased Go decisions from Peer to Social Exclusion, the behavioral change was not associated with a change in the ventral striatal ROI across conditions. The positive association of RPI with increased activity in SMA raises several possible interpretations. Previous studies have found increased SMA activity for selection of action sets (Rushworth et al., 2004), response planning and selection (Liu et al., 2004), and response competition (Ullsperger & von Cramon, 2001). SMA has also shown greater connectivity to striatum during response execution and response inhibition (Duann et al., 2009) and plays a primary role in assessing successful and erroneous motor actions (Bonini et al, 2014). Based on these potential processes, it may be that adolescents with greater resistance to peer influence were better able to engage in the response-related cognitive processes required to maintain performance. However, the current study does not include measures of executive function related to cognitive control (e.g. cognitive interference or inhibitory control tasks), and is thus unable to demonstrate an association between individual differences in those processes with RPI. The lack of a mediation effect of SMA on the association between low RPI and the drop in Go decisions from the Peer to Social Exclusion conditions is also not supportive of a clear role for SMA in explaining the behavioral change. Also notable is the lack of association of the behavioral change with VS or either of the TPJ ROIs. If the drop in Go decisions was related to a decrease in motivation specifically for adolescents with greater susceptibility to peers, a concurrent decrease in VS activity should also be associated with low RPI. Similarly, the lack of association of activity change in anterior or posterior TPJ suggests that RPI is not influencing behavior primarily through a decrease in attention to salient stimuli (Mars, 2012;

Mitchell, 2007) or an increase in social cognition or mentalizing (Saxe & Wexler, 2005).

The negative association of RWR with the drop in striatal activity indicates that individual differences hold the potential to provide insight into the mechanisms of how social contexts can affect decisions. The wide range of processes associated with striatum, including motor planning and execution (Grillner et al., 2007), reinforcement and learning (Schultz, 2013), motivation (Berridge, 2012) and reward valuation (Bartra, McGuire, & Kable, 2013; Diekhof, Kaps, Falkai, & Gruber, 2012), provide a number of possible interpretations of this result. The decrease in striatal activity after social exclusion could represent a lapse in cognitive control for adolescents with higher engagement in risk behaviors, or it could be associated with a drop in motivation relative to adolescents with fewer risk behaviors. Although the effect of RWR behavior on game performance was not mediated by VS activity change after social exclusion, the particular area used for the ROI may be influential. The VS ROI was derived from the Alone condition, representing, as such, a non-social condition in which the subject is attempting to learn and master the task. In that context, the peak BOLD signal coordinates were centered in the ventral striatum, and the extraction of parameter estimates from a 12 mm sphere would result in a greater contribution of ventral than dorsal striatum. Relevant to this, ventral striatum has been related preferentially to tasks associated with processing reward magnitude (Diekhof et al., 2012) and subjective value (Bartra et al., 2013) whereas dorsal striatum has been associated more with cognitive control

(Robertson, Hiebert, Seergobin, Owen, & MacDonald, 2015). This raises the possibility that the behavioral difference in game performance may have been related to reduced cognitive control in adolescents with higher risk behavior which would suggest a deficit in skill rather than motivation. However, a recent study demonstrated that reward and motivation could be dissociated by varying the probability of reward and the level of cognitive interference of the task, with the result that dorsal and lateral striatum (caudate and putamen) were more involved in motivation while ventral striatum (nucleus accumbens) was more involved in reward value (Miller et al., 2014). Without independent measures of cognitive control or subjective ratings of motivation, the results from the current study cannot provide preferential support for either interpretation. In contrast to the previous interpretations that reflect deficits in skill or motivation, the possibility must be addressed that the difference in performance may have been a result of a conscious change in strategy. That is, they may have made an explicit decision to increase their Stop decisions in the (erroneous) belief that a conservative strategy would result in better performance or greater acceptance by the peers. This interpretation, however, seems less likely. Although teens with higher rates of risk behavior exhibited greater decreases in striatal activity during Go decisions following social exclusion, a comparable association between striatal activity and RWR was not found for Stop decisions. If the results were attributable to a strategy change by adolescents with higher RWR, then the relation with striatal response should be seen in Stop decisions as well as Go decisions.

In sum, the results reveal a substantial influence of individual differences and social context on the quality of adolescent decision making. The neuroimaging results suggest the involvement of individual differences in the effect of social context on cognitive control or motivation as possible mechanisms

Limitations and Future Directions

In addition to the limitations of the study extensively discussed in the previous section related to determining the mechanisms associated with the findings, there are several additional limitations to consider. First, the study is a within-subjects design and does not include an experimental manipulation between groups. This limits the ability to attribute behavioral changes *specifically* to the exclusion manipulation because no direct comparison with a control group (i.e. with no exclusion) cannot be made. However, a key revison to the procedure from our previous study (Peake et al., 2013) for the current study was to separate the two Cyberball peer interaction tasks such that the inclusion condition occurred before subjects played the YLG in the Peer condition. This had the effect of making the Peer condition more inclusive, and most importantly, removed the confound of having both a positive peer interaction (Cyberball Inclusion) and negative peer interaction (Cyberball Exclusion) happen between the Peer and Social Exclusion conditions. Also, the sequence of the Peer and Social Exclusion conditions was not counterbalanced, raising concerns about order effects. However, the deception involved in the Cyberball exclusion makes it rather implausible to have subjects suddenly included after being excluded.

Furthermore, the negative affect generated during Cyberball exclusion could linger and potentially interfere with the Peer condition task. For these reasons, it was decided to set a fixed order for all participants. Future research could attempt to avoid any potential residual effects of social exclusion by having two (ostensible) sets of peers. One set of peers would be excluders while the other would be includers.

Future studies of the influence of social exclusion on decision making should add a measure of state affect pre and post exclusion to assess the effect of negative affect. Additional measures should be included to assess baseline cognitive control using a battery of working memory, attention, inhibition, and cognitive interference tasks. If possible, a functional localizer should be added to identify individual neural response patterns for Theory of Mind (Saxe, Brett, & Kanwisher, 2006). The study should also be conducted in a population with higher profiles of risk behavior (i.e. adolescents with juvenile justice system or child welfare system involvement, or low income and inner city youth) to increase the variance in risk behavior. Ideally, this study should provide a follow up session in the future to assess changes in actual risk behavior over time and how those changes relate to the current behavioral and neuroimaging results.

Concluding Comments

In summary, this dissertation suggests that susceptibility to peer influence interacts with the experience of social exclusion to produce maladaptive decision making in adolescents. In the current sample the change in decision quality was associated with reduced engagement of dorsal and ventral striatum, and was predictive of risk behavior in real life. Broadly, the results demonstrate that individual differences *and* social contexts are important factors affecting adolescent decisions and that changes in momentary social acceptance can influence the quality of adolescent decisions, and thereby their performance, in social situations. Accordingly, consideration of these factors should be incorporated alongside cognitive or behavioral methods in order to provide a more nuanced and ecologically valid account of adolescent decision making: namely, to better predict who is at risk and when. An important goal for future studies will be to determine the specific mechanisms involved for individuals who suddenly shift from competent performance to poor decisions in social situations. This study provides a model of how the effect of individual differences and the influence of social contexts can be assessed to improve adolescent outcomes.

REFERENCES CITED

Achenbach, T. M., & Rescorla, L. (2001). *ASEBA school-age forms & profiles.* Aseba Burlington.

Aklin, W. M., Lejuez, C. W., Zvolensky, M. J., Kahler, C. W., & Gwadz, M. (2005). Evaluation of behavioral measures of risk taking propensity with inner city adolescents. *Behaviour Research and Therapy*, *43*(2), 215-28. doi:10.1016/j.brat.2003.12.007

Allen, J. P., Chango, J., Szwedo, D., Schad, M., & Marston, E. (2012). Predictors of susceptibility to peer influence regarding substance use in adolescence. *Child Development*, *83*(1), 337-50. doi:10.1111/j.1467-8624.2011.01682.x

Ashburner, J. (2007). A fast diffeomorphic image registration algorithm. *NeuroImage*, *38*(1), 95-113.

Ayduk, O., Gyurak, A., & Luerssen, A. (2008). Individual differences in the rejection-aggression link in the hot sauce paradigm: The case of rejection sensitivity. *Journal of Experimental Social Psychology*, *44*(3), 775-782. doi:10.1016/j.jesp.2007.07.004

Bartra, O., McGuire, J. T., & Kable, J. W. (2013). The valuation system: a coordinate-based meta-analysis of BOLD fMRI experiments examining neural correlates of subjective value. *Neuroimage, 76*, 412-427.

Bault, N., Joffily, M., Rustichini, A., & Coricelli, G. (2011). Medial prefrontal cortex and striatum mediate the influence of social comparison on the decision process. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(38), 16044-9. doi:10.1073/pnas.1100892108

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*(1-3), 7-15.

Berridge, K. C. (2012). From prediction error to incentive salience: mesolimbic computation of reward motivation. *European Journal of Neuroscience, 35*(7), 1124-1143.

Beyth-Marom, R., Austin, L., Fischhoff, B., Palmgren, C., & Jacobs-Quadrel, M. (1993). Perceived consequences of risky behaviors: Adults and adolescents. *Developmental Psychology*, *29*(3), 549.

Birmaher, B., Khetarpal, S., Brent, D., Cully, M., Balach, L., Kaufman, J., & NEER, S. M. (1997). The screen for child anxiety related emotional disorders (SCARED): Scale construction and psychometric characteristics. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(4), 545-553.

Bjork, J. M., Lynne-Landsman, S. D., Sirocco, K., & Boyce, C. A. (2012). Brain maturation and risky behavior: The promise and the challenges of neuroimaging-based accounts. *Child Development Perspectives*, *6*(4), 385-391.

Bolling, D. Z., Pitskel, N. B., Deen, B., Crowley, M. J., Mayes, L. C., & Pelphrey, K. A. (2011a). Development of neural systems for processing social exclusion from childhood to adolescence. *Developmental Science.*

Bolling, D. Z., Pitskel, N. B., Deen, B., Crowley, M. J., McPartland, J. C., Mayes, L. C., & Pelphrey, K. A. (2011b). Dissociable brain mechanisms for processing social exclusion and rule violation. *NeuroImage*, *54*(3), 2462-2471.

Bonini, F., Burle, B., Liégeois-Chauvel, C., Régis, J., Chauvel, P., & Vidal, F. (2014). Action monitoring and medial frontal cortex: leading role of supplementary motor area. *Science, 343*(6173), 888-891.

Brand, M., Labudda, K., & Markowitsch, H. J. (2006). Neuropsychological correlates of decision-making in ambiguous and risky situations. *Neural Networks : The Official Journal of the International Neural Network Society*, *19*(8), 1266-76. doi:10.1016/j.neunet.2006.03.001

Brechwald, W. A., & Prinstein, M. J. (2011). Beyond homophily: A decade of advances in understanding peer influence processes. *Journal of Research on Adolescence*, *21*(1), 166-179.

Carter, P. M., Bingham, C. R., Zakrajsek, J. S., Shope, J. T., & Sayer, T. B. (2014). Social norms and risk perception: Predictors of distracted driving behavior among novice adolescent drivers. *The Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine*, *54*(5 Suppl), S32-41. doi:10.1016/j.jadohealth.2014.01.008

Carter-Sowell, A. R., Chen, Z., & Williams, K. D. (2008). Ostracism increases social susceptibility. *Social Influence*, *3*(3), 143-153. doi:10.1080/15534510802204868

Casey, B. J., Jones, R. M., & Somerville, L. H. (2011). Braking and accelerating of the adolescent brain. *Journal of Research on Adolescence*, *21*(1), 21-33.

Cavalca, E., Kong, G., Liss, T., Reynolds, E. K., Schepis, T. S., Lejuez, C. W., & Krishnan-Sarin, S. (2013). A preliminary experimental investigation of peer influence on risk-taking among adolescent smokers and non-smokers. *Drug and Alcohol Dependence*, *129*(1-2), 163-6. doi:10.1016/j.drugalcdep.2012.09.020

Caviness, V. S., Jr, Meyer, J., Makris, N., & Kennedy, D. N. (1996). MRI-Based Topographic Parcellation of Human Neocortex: An Anatomically Specified Method with Estimate of Reliability. Journal of Cognitive Neuroscience. 8(6):566-87. doi: 10.1162/jocn.1996.8.6.566.

Charles, V. E., & Blum, R. W. (2008). Core competencies and the prevention of high-risk sexual behavior. *New Directions for Child and Adolescent Development*, *2008*(122), 61-74. doi:10.1002/cd.229

Chein, J., Albert, D., OBrien, L., Uckert, K., & Steinberg, L. (2011). Peers increase adolescent risk taking by enhancing activity in the brain’s reward circuitry. *Developmental Science.*

Christopoulos, G. I., Tobler, P. N., Bossaerts, P., Dolan, R. J., & Schultz, W. (2009). Neural correlates of value, risk, and risk aversion contributing to decision making under risk. *The Journal of Neuroscience*, *29*(40), 12574.

Cohen, J. R., Asarnow, R. F., Sabb, F. W., Bilder, R. M., Bookheimer, S. Y., Knowlton, B. J., & Poldrack, R. A. (2010). A unique adolescent response to reward prediction errors. *Nature Neuroscience*, *13*(6), 669-71. doi:10.1038/nn.2558

Cohn, L. D., Macfarlane, S., Yanez, C., & Imai, W. K. (1995). Risk-perception: Differences between adolescents and adults. *Health Psychology*, *14*(3), 217.

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron*, *58*(3), 306-324.

Cyders, M. A., Smith, G. T., Spillane, N. S., Fischer, S., Annus, A. M., & Peterson, C. (2007). Integration of impulsivity and positive mood to predict risky behavior: Development and validation of a measure of positive urgency. *Psychological Assessment*, *19*(1), 107-18. doi:10.1037/1040-3590.19.1.107

Dayan, P., & Balleine, B. W. (2002). Reward, motivation, and reinforcement learning. *Neuron*, *36*(2), 285-298.

Desikan, R. S., Segonne, F., Fischl, B., Quinn, B. T., Dickerson, B. C., et al. (2006). An Automated Labeling System for Subdividing the Human Cerebral Cortex on MRI Scans into Gyral Based Regions of Interest. Neuroimage, 31(3), 968-980.

DeWall, C. N., Baumeister, R. F., & Vohs, K. D. (2008). Satiated with belongingness? Effects of acceptance, rejection, and task framing on self-regulatory performance. *Journal of Personality and Social Psychology*, *95*(6), 1367.

DeWall, C. N., Maner, J. K., & Rouby, D. A. (2009). Social exclusion and early-stage interpersonal perception: Selective attention to signs of acceptance. *Journal of Personality and Social Psychology*, *96*(4), 729-41. doi:10.1037/a0014634

Diekhof, E. K., Kaps, L., Falkai, P., & Gruber, O. (2012). The role of the human ventral striatum and the medial orbitofrontal cortex in the representation of reward magnitude - an activation likelihood estimation meta-analysis of neuroimaging studies of passive reward expectancy and outcome processing. *Neuropsychologia*, *50*(7), 1252-66. doi:10.1016/j.neuropsychologia.2012.02.007

Dishion, T. J., Ha, T., & Véronneau, M. H. (2012). An ecological analysis of the effects of deviant peer clustering on sexual promiscuity, problem behavior, and childbearing from early adolescence to adulthood: An enhancement of the life history framework. *Developmental Psychology*, *48*(3), 703.

Downey, G., & Feldman, S. I. (1996). Implications of rejection sensitivity for intimate relationships. *Journal of Personality and Social Psychology*, *70*(6), 1327-43.

Downey, G., Lebolt, A., Rincón, C., & Freitas, A. L. (1998). Rejection sensitivity and children's interpersonal difficulties. *Child Development*, *69*(4), 1074-1091.

Duann, J. R., Ide, J. S., Luo, X., & Li, C. S. R. (2009). Functional connectivity delineates distinct roles of the inferior frontal cortex and presupplementary motor area in stop signal inhibition. *The Journal of Neuroscience, 29*(32), 10171-10179.

Dworkin, J. (2005). Risk taking as developmentally appropriate experimentation for college students. *Journal of Adolescent Research*, *20*(2), 219. doi:10.1177/0743558404273073

Eaton, D. K., Kann, L., Kinchen, S., Shanklin, S., Flint, K. H., Hawkins, J., . . . Chyen, D. (2012). Youth risk behavior surveillance-united states, 2011. *MMWR. Surveillance Summaries : Morbidity and Mortality Weekly Report. Surveillance Summaries / CDC*, *61*(4), 1-162.

Ernst, M., & Fudge, J. L. (2009). A developmental neurobiological model of motivated behavior: Anatomy, connectivity and ontogeny of the triadic nodes. *Neuroscience and Biobehavioral Reviews*, *33*(3), 367-82. doi:10.1016/j.neubiorev.2008.10.009

Ernst, M., Nelson, E. E., Jazbec, S., McClure, E. B., Monk, C. S., Leibenluft, E., . . . Pine, D. S. (2005). Amygdala and nucleus accumbens in responses to receipt and omission of gains in adults and adolescents. *NeuroImage*, *25*(4), 1279-91. doi:10.1016/j.neuroimage.2004.12.038

Ernst, M., Romeo, R. D., & Andersen, S. L. (2009). Neurobiology of the development of motivated behaviors in adolescence: A window into a neural systems model. *Pharmacology, Biochemistry, and Behavior*, *93*(3), 199-211. doi:10.1016/j.pbb.2008.12.013

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion (Washington, D.C.)*, *7*(2), 336-53. doi:10.1037/1528-3542.7.2.336

Falk, E. B., Cascio, C. N., O'Donnell, M. B., Carp, J., Tinney, F. J., Bingham, C. R., . . . Simons-Morton, B. G. (2014). Neural responses to exclusion predict susceptibility to social influence. *The Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine*, *54*(5 Suppl), S22-31. doi:10.1016/j.jadohealth.2013.12.035

Felitti, M. D., Vincent, J., Anda, M. D., Robert, F., Nordenberg, M. D., Williamson, M. S., . . . Edwards, B. A. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: The adverse childhood experiences (ACE) study. *American Journal of Preventive Medicine*, *14*(4), 245-258.

Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. U. (2009). Affective and deliberative processes in risky choice: Age differences in risk taking in the columbia card task. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *35*(3), 709-30. doi:10.1037/a0014983

Fischhoff, B. (2008). Assessing adolescent decision-making competence. *Developmental Review : DR*, *28*(1), 12-28. doi:10.1016/j.dr.2007.08.001

Fliessbach, K., Weber, B., Trautner, P., Dohmen, T., Sunde, U., Elger, C. E., & Falk, A. (2007). Social comparison affects reward-related brain activity in the human ventral striatum. *Science (New York, N.Y.)*, *318*(5854), 1305-8. doi:10.1126/science.1145876

Galvan, A., Hare, T. A., Parra, C. E., Penn, J., Voss, H., Glover, G., & Casey, B. J. (2006). Earlier development of the accumbens relative to orbitofrontal cortex might underlie risk-taking behavior in adolescents. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *26*(25), 6885-92. doi:10.1523/JNEUROSCI.1062-06.2006

Gardner, M., & Steinberg, L. (2005a). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. *Developmental Psychology*, *41*(4), 625-634.

Gardner, M., & Steinberg, L. (2005b). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. *Developmental Psychology*, *41*(4), 625-634.

Grill-Spector, K., Henson, R., & Martin, A. (2006). Repetition and the brain: Neural models of stimulus-specific effects. *Trends in Cognitive Sciences*, *10*(1), 14-23. doi:10.1016/j.tics.2005.11.006

Grillner, S., Hellgren, J., Menard, A., Saitoh, K., & Wikström, M. A. (2005). Mechanisms for selection of basic motor programs–roles for the striatum and pallidum. *Trends in neurosciences, 28*(7), 364-370.

Haddad, A. D., Harrison, F., Norman, T., & Lau, J. Y. (2014). Adolescent and adult risk-taking in virtual social contexts. *Frontiers in Psychology*, *5*, 1476. doi:10.3389/fpsyg.2014.01476

Hopko, D. R., Lejuez, C. W., Daughters, S. B., Aklin, W. M., Osborne, A., Simmons, B. L., & Strong, D. R. (2006). Construct validity of the balloon analogue risk task (BART): Relationship with MDMA use by inner-city drug users in residential treatment. *Journal of Psychopathology and Behavioral Assessment*, *28*(2), 95-101. doi:10.1007/s10862-006-7487-5

Hoyle, R. H., Stephenson, M. T., Palmgreen, P., Lorch, E. P., & Donohew, R. L. (2002). Reliability and validity of a brief measure of sensation seeking. *Personality and Individual Differences*, *32*(3), 401-414.

Hutchinson, J. B., Uncapher, M. R., & Wagner, A. D. (2009). Posterior parietal cortex and episodic retrieval: Convergent and divergent effects of attention and memory. *Learning & Memory (Cold Spring Harbor, N.Y.)*, *16*(6), 343-56. doi:10.1101/lm.919109

Jessor, R., & Jessor, S. L. (1975). Adolescent development and the onset of drinking; a longitudinal study. *Journal of Studies on Alcohol and Drugs*, *36*(01), 27.

Johnson, S. B., Blum, R. W., & Giedd, J. N. (2009). Adolescent maturity and the brain: The promise and pitfalls of neuroscience research in adolescent health policy. *Journal of Adolescent Health*, *45*(3), 216-221.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263-291.

Knutson, B., Delgado, M. R., & Phillips, P. E. M. (2008). Representation of subjective value in the striatum. *Neuroeconomics: Decision Making and the Brain (Glimcher PW, Camerer CF, Fehr E, Poldrack RA, Eds)*, 389-406.

Langner, R., Steinborn, M. B., Chatterjee, A., Sturm, W., & Willmes, K. (2010). Mental fatigue and temporal preparation in simple reaction-time performance. *Acta Psychologica*, *133*(1), 64-72. doi:10.1016/j.actpsy.2009.10.001

Larsman, P., Eklöf, M., & Törner, M. (2012). Adolescents' risk perceptions in relation to risk behavior with long-term health consequences; antecedents and outcomes: A literature review. *Safety Science*, *50*(9), 1740-1748.

Lejuez, C. W., Aklin, W. M., Bornovalova, M. A., & Moolchan, E. T. (2005). Differences in risk-taking propensity across inner-city adolescent ever- and never-smokers. *Nicotine & Tobacco Research*, *7*(1), 71-79. doi:10.1080/14622200412331328484

Lejuez, C. W., Simmons, B. L., Aklin, W. M., Daughters, S. B., & Dvir, S. (2004). Risk-taking propensity and risky sexual behavior of individuals in residential substance use treatment. *Addictive Behaviors*, *29*(8), 1643-1647.

Levita, L., Hoskin, R., & Champi, S. (2012). Avoidance of harm and anxiety: A role for the nucleus accumbens. *NeuroImage.* doi:10.1016/j.neuroimage.2012.04.059

Liu, X., Banich, M. T., Jacobson, B. L., & Tanabe, J. L. (2004). Common and distinct neural substrates of attentional control in an integrated Simon and spatial Stroop task as assessed by event-related fMRI. *NeuroImage, 22*(3), 1097-1106.

Mackey, A. P., Raizada, R. D. S., & Bunge, S. A. (2013). Environmental influences on prefrontal development. In D. T. Stuss & R. T. Knight (Eds.), Principles of Frontal Lobe Function (pp.   ). New York, NY: Oxford University Press.

Mallott, M. A., Maner, J. K., DeWall, N., & Schmidt, N. B. (2009). Compensatory deficits following rejection: The role of social anxiety in disrupting affiliative behavior. *Depression and Anxiety*, *26*(5), 438-446.

Maner, J. K., DeWall, C. N., Baumeister, R. F., & Schaller, M. (2007). Does social exclusion motivate interpersonal reconnection? Resolving the" porcupine problem". *Journal of Personality and Social Psychology*, *92*(1), 42.

Mars, R. B., Sallet, J., Schüffelgen, U., Jbabdi, S., Toni, I., & Rushworth, M. F. (2012). Connectivity-based subdivisions of the human right “temporoparietal junction area”: evidence for different areas participating in different cortical networks. *Cerebral cortex, 22*(8), 1894-1903.

May, J. C., Delgado, M. R., Dahl, R. E., Stenger, V. A., Ryan, N. D., Fiez, J. A., & Carter, C. S. (2004). Event-related functional magnetic resonance imaging of reward-related brain circuitry in children and adolescents. *Biological Psychiatry*, *55*(4), 359-66. doi:10.1016/j.biopsych.2003.11.008

Metzler, C. W. (2001). Evaluation of a comprehensive behavior management program to improve school-wide positive behavior support. *Education and Treatment of Children*, *24*(4), 448-479.

Miller, E. M., Shankar, M. U., Knutson, B., & McClure, S. M. (2014). Dissociating motivation from reward in human striatal activity. *Journal of cognitive neuroscience, 26*(5), 1075-1084.

Mitchell, J. P. (2008). Activity in right temporo-parietal junction is not selective for theory-of-mind. *Cerebral Cortex (New York, N.Y. : 1991)*, *18*(2), 262-71. doi:10.1093/cercor/bhm051

Monahan, K. C., Steinberg, L., & Cauffman, E. (2009). Affiliation with antisocial peers, susceptibility to peer influence, and antisocial behavior during the transition to adulthood. *Developmental Psychology*, *45*(6), 1520-30. doi:10.1037/a0017417

Nelson, E. E., Leibenluft, E., McCLURE, E. B., & Pine, D. S. (2005). The social re-orientation of adolescence: A neuroscience perspective on the process and its relation to psychopathology. *Psychological Medicine*, *35*(02), 163-174. doi:10.1017/S0033291704003915

Oaten, M., Williams, K. D., Jones, A., & Zadro, L. (2008). The effects of ostracism on self-regulation in the socially anxious. *Journal of Social and Clinical Psychology*, *27*(5), 471-504.

O'Brien, L., Albert, D., Chein, J., & Steinberg, L. (2011). Adolescents prefer more immediate rewards when in the presence of their peers. *Journal of Research on Adolescence*, *21*(4), 747-753. doi:10.1111/j.1532-7795.2011.00738.x

Overman, W. H., Frassrand, K., Ansel, S., Trawalter, S., Bies, B., & Redmond, A. (2004). Performance on the IOWA card task by adolescents and adults. *Neuropsychologia*, *42*(13), 1838-1851.

Patterson, G. R., Dishion, T. J., & Yoerger, K. (2000). Adolescent growth in new forms of problem behavior: Macro- and micro-peer dynamics. *Prevention Science : The Official Journal of the Society for Prevention Research*, *1*(1), 3-13.

Peake, S. J., Dishion, T. J., Stormshak, E. A., Moore, W. E., & Pfeifer, J. H. (2013). Risk-taking and social exclusion in adolescence: Neural mechanisms underlying peer influences on decision-making. *NeuroImage.* doi:10.1016/j.neuroimage.2013.05.061

Petersen, A. C., Crockett, L., Richards, M., & Boxer, A. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence*, *17*(2), 117-133.

Piehler, T. F., & Dishion, T. J. (2007). Interpersonal dynamics within adolescent friendships: Dyadic mutuality, deviant talk, and the development of antisocial behavior. *Child Development*, *78*(5), 1611-1624.

Prinstein, M. J., Boergers, J., & Vernberg, E. M. (2001). Overt and relational aggression in adolescents: Social-psychological adjustment of aggressors and victims. *Journal of Clinical Child Psychology*, *30*(4), 479-491.

Prinstein, M. J., Brechwald, W. A., & Cohen, G. L. (2011). Susceptibility to peer influence: Using a performance-based measure to identify adolescent males at heightened risk for deviant peer socialization. *Developmental Psychology*, *47*(4), 1167-72. doi:10.1037/a0023274

Quadrel, M. J., Fischhoff, B., & Davis, W. (1993). Adolescent (in) vulnerability. *American Psychologist*, *48*(2), 102.

Rao, U., Sidhartha, T., Harker, K. R., Bidesi, A. S., Chen, L. A., & Ernst, M. (2011). Relationship between adolescent risk preferences on a laboratory task and behavioral measures of risk-taking. *The Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine*, *48*(2), 151-8. doi:10.1016/j.jadohealth.2010.06.008

Reyna, V. F., & Farley, F. (2006). Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological Science in the Public Interest*, *7*(1), 1-44.

Reynolds, E. K., Schreiber, W. M., Geisel, K., MacPherson, L., Ernst, M., & Lejuez, C. W. (2013). Influence of social stress on risk-taking behavior in adolescents. *Journal of Anxiety Disorders*, *27*(3), 272-7. doi:10.1016/j.janxdis.2013.02.010

Richards, J. M., Plate, R. C., & Ernst, M. (2013). A systematic review of fmri reward paradigms used in studies of adolescents vs. Adults: The impact of task design and implications for understanding neurodevelopment. *Neuroscience and Biobehavioral Reviews*, *37*(5), 976-91. doi:10.1016/j.neubiorev.2013.03.004

Robertson, B. D., Hiebert, N. M., Seergobin, K. N., Owen, A. M., & MacDonald, P. A. (2015). Dorsal striatum mediates cognitive control, not cognitive effort per se, in decision-making: An event-related fMRI study. *NeuroImage, 114*, 170-184.

Romer, D. (2010). Adolescent risk taking, impulsivity, and brain development: Implications for prevention. *Developmental Psychobiology*, *52*(3), 263-276.

Rushworth, M. F. S., Walton, M. E., Kennerley, S. W., & Bannerman, D. M. (2004). Action sets and decisions in the medial frontal cortex. *Trends in cognitive sciences, 8*(9), 410-417.

Saxe, R., Brett, M., & Kanwisher, N. (2006). Divide and conquer: A defense of functional localizers. *NeuroImage, 30*, 1088-1096.

Saxe, R., & Kanwisher, N. (2003). People thinking about thinking people: The role of the temporo parietal junction in" theory of mind". *Social Neuroscience: Key Readings*, 171.

Saxe, R., & Wexler, A. (2005). Making sense of another mind: the role of the right temporo-parietal junction. *Neuropsychologia, 43*(10), 1391-1399.

Schonberg, T., Fox, C. R., & Poldrack, R. A. (2011). Mind the gap: Bridging economic and naturalistic risk-taking with cognitive neuroscience. *Trends in Cognitive Sciences*, *15*(1), 11-9. doi:10.1016/j.tics.2010.10.002

Schultz, W. (2013). Updating dopamine reward signals. *Current opinion in neurobiology, 23*(2), 229-238.

Scott-Parker, B., Watson, B., & King, M. J. (2009). Understanding the psychosocial factors influencing the risky behaviour of young drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *12*(6), 470-482.

Shope, J. T., & Bingham, C. R. (2008). Teen driving: Motor-vehicle crashes and factors that contribute. *American Journal of Preventive Medicine*, *35*(3 Suppl), S261-71. doi:10.1016/j.amepre.2008.06.022

Simon, D., Becker, M. P., Mothes-Lasch, M., Miltner, W. H., & Straube, T. (2014). Effects of social context on feedback-related activity in the human ventral striatum. *NeuroImage.*

Simons-Morton, B., Lerner, N., & Singer, J. (2005). The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident; Analysis and Prevention*, *37*(6), 973-82. doi:10.1016/j.aap.2005.04.014

Slovic, P., Peters, E., Finucane, M. L., & Macgregor, D. G. (2005). Affect, risk, and decision making. *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association*, *24*(4 Suppl), S35-40. doi:10.1037/0278-6133.24.4.S35

Somerville, L. H., Jones, R. M., & Casey, B. J. (2010). A time of change: Behavioral and neural correlates of adolescent sensitivity to appetitive and aversive environmental cues. *Brain and Cognition*, *72*(1), 124-33. doi:10.1016/j.bandc.2009.07.003

Somerville, L. H., Kelley, W. M., & Heatherton, T. F. (2010). Self-esteem modulates medial prefrontal cortical responses to evaluative social feedback. *Cerebral Cortex (New York, N.Y. : 1991)*, *20*(12), 3005-13. doi:10.1093/cercor/bhq049

Spinella, M. (2007). Normative data and a short form of the barratt impulsiveness scale. *International Journal of Neuroscience*, *117*(3), 359-368.

Starcke, K., & Brand, M. (2012). Decision making under stress: A selective review. *Neuroscience and Biobehavioral Reviews*, *36*(4), 1228-48. doi:10.1016/j.neubiorev.2012.02.003

Steinberg, L. (2010). A dual systems model of adolescent risk-taking. *Developmental Psychobiology*, *52*(3), 216-224.

Steinberg, L., & Monahan, K. C. (2007). Age differences in resistance to peer influence. *Developmental Psychology*, *43*(6), 1531-43. doi:10.1037/0012-1649.43.6.1531

Stroud, L. R., Foster, E., Papandonatos, G. D., Handwerger, K., Granger, D. A., Kivlighan, K. T., & Niaura, R. (2009). Stress response and the adolescent transition: Performance versus peer rejection stressors. *Development and Psychopathology*, *21*(1), 47-68. doi:10.1017/S0954579409000042

Torrubia, R., Avila, C., Moltó, J., & Caseras, X. (2001). The sensitivity to punishment and sensitivity to reward questionnaire (SPSRQ) as a measure of gray's anxiety and impulsivity dimensions. *Personality and Individual Differences*, *31*(6), 837-862.

Twenge, J. M., Catanese, K. R., & Baumeister, R. F. (2002). Social exclusion causes self-defeating behavior. *Journal of Personality and Social Psychology*, *83*(3), 606.

Tymula, A., Rosenberg Belmaker, L. A., Roy, A. K., Ruderman, L., Manson, K., Glimcher, P. W., & Levy, I. (2012). Adolescents' risk-taking behavior is driven by tolerance to ambiguity. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(42), 17135-40. doi:10.1073/pnas.1207144109

Ullsperger, M., & von Cramon, D. Y. (2001). Subprocesses of performance monitoring: a dissociation of error processing and response competition revealed by event-related fMRI and ERPs. *NeuroImage, 14*(6), 1387-1401.

Uncapher, M. R., & Wagner, A. D. (2009). Posterior parietal cortex and episodic encoding: Insights from fmri subsequent memory effects and dual-attention theory. *Neurobiology of Learning and Memory*, *91*(2), 139-54. doi:10.1016/j.nlm.2008.10.011

van den Bos, R., Harteveld, M., & Stoop, H. (2009). Stress and decision-making in humans: Performance is related to cortisol reactivity, albeit differently in men and women. *Psychoneuroendocrinology*, *34*(10), 1449-58. doi:10.1016/j.psyneuen.2009.04.016

Van Leijenhorst, L., Zanolie, K., Van Meel, C. S., Westenberg, P. M., Rombouts, S. A., & Crone, E. A. (2010). What motivates the adolescent? Brain regions mediating reward sensitivity across adolescence. *Cerebral Cortex (New York, N.Y. : 1991)*, *20*(1), 61-9. doi:10.1093/cercor/bhp078

Van Overwalle, F., & Baetens, K. (2009). Understanding others' actions and goals by mirror and mentalizing systems: A meta-analysis. *NeuroImage*, *48*(3), 564-84. doi:10.1016/j.neuroimage.2009.06.009

Wagner, A. D., Shannon, B. J., Kahn, I., & Buckner, R. L. (2005). Parietal lobe contributions to episodic memory retrieval. *Trends in Cognitive Sciences*, *9*(9), 445-53. doi:10.1016/j.tics.2005.07.001

Weber, E. U., Shafir, S., & Blais, A. R. (2004). Predicting risk sensitivity in humans and lower animals: Risk as variance or coefficient of variation. *Psychological Review*, *111*(2), 430-45. doi:10.1037/0033-295X.111.2.430

Wechsler, D. (1999). *Wechsler abbreviated scale of intelligence.* Psychological Corporation.

Weissman, M. M., Orvaschel, H., & Padian, N. (1980). Children's symptom and social functioning self-report scales comparison of mothers' and children's reports. *The Journal of Nervous and Mental Disease*, *168*(12), 736-740.

Wendler, E., Gaspar, J. C., Ferreira, T. L., Barbiero, J. K., Andreatini, R., Vital, M. A., . . . Da Cunha, C. (2013). The roles of the nucleus accumbens core, dorsomedial striatum, and dorsolateral striatum in learning: Performance and extinction of pavlovian fear-conditioned responses and instrumental avoidance responses. *Neurobiology of Learning and Memory.* doi:10.1016/j.nlm.2013.11.009

Williams, K. D., Cheung, C. K., & Choi, W. (2000). Cyberostracism: Effects of being ignored over the internet. *Journal of Personality and Social Psychology*, *79*(5), 748-62.