RUNNING HEAD: PARENT-ADOLESCENT CONFLICT AND ADOLESCENT RISK-
TAKING PROPENSITY

Moderated mediation of the link between parent-adolescent conflict and adolescent risk-taking: The role of physiological regulation and hostile behavior in an experimentally controlled investigation

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Abstract

Compared to childhood and adulthood, adolescence is a time of greater risk-taking behavior, potentially resulting in serious consequences. Theories of adolescent brain development highlight the imbalance between neural circuitry for reward vs. regulation. Although this imbalance may make adolescents more vulnerable to impaired decision-making in the context of heightened arousal, not all adolescents exhibit problematic risk behavior, suggesting other factors are involved. Relatedly, parent-adolescent conflict increases in mid-adolescence, and is linked to negative outcomes like substance use related risk-taking. However, the mechanism by which parent-adolescent conflict and risk-taking are linked is still unknown. Therefore, we investigated this association using a multi-method experimental design. Parent-adolescent dyads were randomly assigned to complete a discussion task together on the topic of either the adolescent's dream vacation or an adolescent-identified conflict topic. During the task, adolescent peripheral psychophysiology was measured for later calculation of heart rate variability (HRV), an index of self-regulation. Immediately after the discussion task, adolescents completed a performance-based measure of risk-taking propensity that indexes real-world risk behaviors. We hypothesized that parent-adolescent conflict would predict greater adolescent risk-taking propensity, and that increased behavioral arousal in the context of conflict, coupled with impaired self-regulation, would explain this link. Results indicated no direct effect of parent-adolescent conflict on adolescent risk-taking propensity. However, there was a significant conditional indirect effect: lower HRV, indexing worse regulatory ability, mediated the relation between conflict and risk-taking propensity but only for adolescents exhibiting behavioral arousal during the discussion task. We discuss implications for understanding adolescent risk-taking behavior.

Keywords: adolescents; risk-taking; parent-adolescent conflict; hostility; heart rate variability

Adolescence is characterized by development in social, physical, and neurobiological domains. With greater independence during this time period comes an increasing amount of choices adolescents can make about their behavior. Of relevance, adolescence is a time of significantly greater engagement in behaviors with a high risk of causing harm (i.e., *risk behaviors*), relative to other age periods, as seen in increased reports of impaired and distracted driving, suicidal behavior, and substance use (Defoe et al. 2015; Kann et al. 2016). Risk behavior results from a decision-making process in which an individual selects the choice with the greatest range of potential (uncertain) outcomes instead of an option with one certain outcome (Defoe et al. 2015). Notably, increased engagement in risk behavior occurs in adolescence for both humans and animals, suggesting it serves an evolutionarily adaptive role in development by increasing social behavior and independence (Spear 2011). However, risk behavior can be problematic when it results in a deviation from typical adolescent development or results in a trajectory limiting future academic or occupational attainment (e.g., not completing high school, incarceration).

Although all people undergo substantial development during adolescence, not all adolescents engage in problematic risk behavior. Consequently, there is a pressing need to understand individual and contextual factors that increase the likelihood of problematic adolescent risk behavior. Along those lines, conflict intensity between parents and adolescents also increases in adolescence, and, at its extreme, is associated with adverse youth outcomes, including depression and risk behaviors (Laursen et al. 1998; Weymouth et al. 2016). While the mechanism of this association remains unclear, experiencing acute stress, such as conflictual interactions with parents, may affect adolescents' decision-making for risk behaviors (Galvan and Rahdar 2013; Uy and Galvan 2017). In the current study, we sought to investigate how the experience of parent-adolescent conflict impacts adolescent risk-taking, using behavioral and physiological indicators of arousal and self-regulation, respectively. Understanding how parent-adolescent conflict is related to risk-taking is essential because the experience of social stress may potentiate the already-existing heightened risk for adverse outcomes in adolescence (Uy and Galvan 2017).

Parent-adolescent Conflict and Measurement of Social Stress Correlates

Conflict between parents and adolescents is normative and can be adaptive insofar as it is a vehicle for learning skills like problem-solving and negotiation. However, aversive and prolonged conflict may have negative consequences because, depending on the frequency and intensity, it can be perceived as a stressor to adolescents (Laursen and Hafen 2010). These interactions pose risk for poor psychosocial outcomes among adolescents, including the development of externalizing disorders, delinquency, substance abuse, harmful risk-taking behaviors, and general maladjustment (Ary et al. 1999; Burt et al. 2003; Dmitrieva et al. 2004; Duncan et al. 1998; Klahr et al. 2011; Van Doorn et al. 2008; Weymouth et al. 2016). Interestingly, it is not the frequency of conflict between parents and youth that increases in adolescence, but rather its emotional intensity (Laursen et al. 1998). These interactions are characterized by dysfunctional conflict resolution strategies, such as expressions of hostile behavior that may include invalidation, mocking, and character assassinations, which in turn may lead to heightened physiological arousal and difficulty managing intense emotions (Chaplin et al. 2012; Crowell et al. 2013).

Along those lines, hostility is an observable, commonly used metric of a behavioral arousal response to social stress in the context of conflict. Indeed, hostility has been linked to cardiac indices due to its impact on the autonomic nervous system (Chida and Hamer 2008; Chida and Steptoe 2009; Luecken and Roubinov 2012). It is also considered a poor conflict management strategy given its potential to escalate negative emotions and thus may be a barrier to effective problem-solving. Most parent-adolescent dyads do not exhibit intense hostility, with a recent study finding about 70% of dyads exhibited low hostility during a laboratory conflict task (Glatz et al. 2019). However, high adolescent hostility is related to externalizing behaviors like aggression, as well as other adverse outcomes like delinquent behavior, internalizing symptoms, and general maladjustment (Buehler 2006; Fosco et al. 2014; Glatz et al. 2019; Van Doorn et al. 2008; Weymouth et al. 2016), highlighting the need for better understanding of this characteristic. Importantly, recent findings suggest that it is adolescent-to-parent hostility that is a better predictor of both concurrent and longitudinal adverse outcomes, such as the aforementioned externalizing behaviors (Fosco et al. 2014; Glatz et al. 2019), yet adolescent-to-

parent hostility is understudied relative to parent-to-adolescent hostility (Glatz et al. 2019). Lastly, adolescent self-reports of anger are related to their risk behaviors (Curry and Youngblade 2006). It follows that hostility, an expression of negative affect similar to anger, may also be relevant in both parent-adolescent conflict and adolescent engagement in risk behaviors.

Despite the association between conflict and adolescent engagement in risk-behaviors, it is difficult to determine whether there is a common etiology, such as an underlying genetic vulnerability for conflict and externalizing traits (Burt et al. 2003), or whether conflict has a proximal, temporally-related effect on adolescent risk behavior. If conflict is a proximal, predisposing factor for subsequent engagement in risk behavior, rather than only a correlate, one mechanism explaining this link may be the impact of social stress.

Accordingly, one hypothesized explanation of the link between parent-adolescent conflict and adolescent risk behavior is that adolescents perceive these interactions as stressful, and the impact of increased stress on their self-regulatory ability leads to adolescents' impaired decision-making abilities in the context of engagement in risk behaviors (Jamieson and Mendes 2016; Laursen and Hafen 2010; Liston et al. 2009). That is, inability to self-regulate during the experience of stress may mediate the link between parent-adolescent conflict and risky behavior. A potential mechanism for this phenomenon is that increased stress, including social stress, is linked to decreased prefrontal cortex (PFC) activity, implicated in self-regulation processes and executive functioning (Arnsten 1999; Arnsten et al. 2015; Hermans et al. 2014; Liston et al. 2009; Qin et al. 2009). A relatively non-invasive means of measuring individual differences in self-regulation ability is heart rate variability (HRV), an index of parasympathetic-mediated top-down control measured using peripheral psychophysiology. HRV is defined as "the millisecond variation between consecutive heartbeats and reflects the pulse of vagal nerve activity on the sinoatrial node" (Kemp et al. 2017, pg. 547). According to the neurovisceral integration theory, HRV is an indirect measure of PFC functioning (Thayer and Lane 2009). Empirical research supports this assertion, such that HRV predicts both activity within the PFC and self-control in the context of rewarding stimuli (Maier and Hare 2017). Moreover, a meta-analysis confirmed a positive relation between HRV and top-down regulatory control ($r = 0.09$, $p < 0.001$; Holzman and Bridgett 2017). Therefore, HRV appears to index individual differences in the ability to exert

self-control (Beauchaine and Thayer 2015; Holzman and Bridgett 2017; Kemp et al. 2017; Maier and Hare 2017; Thayer and Lane 2009) and may represent an optimal method of measuring regulatory ability in stressful situations. Furthermore, self-control is inversely related to adolescent risk behavior (Curry and Youngblade 2006), and therefore may be an important construct in characterizing the link between parent-adolescent conflict and adolescent risk behavior.

The robust link between stress and impaired decision-making was recently affirmed in a meta-analysis ($d = .17$; Starcke and Brand 2016). When considered jointly, two theories underpinning this link—the dual process theory (Evans 2003) and the attentional narrowing hypothesis (Derryberry and Tucker 1994; Easterbrook 1959)—propose that when exposed to a stressor (e.g., conflict with a parent), the body adapts to the stressor by conserving energy. In doing so, the body allocates limited resources to focus only on the most essential information, without the greater context encapsulating the stressor. Given these conditions, behavior based on intuition rather than calculation (e.g., automatic) is expected. There is empirical support for both theories in the context of altered decision-making under stress (Porcelli and Delgado 2009; Wichary et al. 2016). In sum, there are fewer cognitive resources available to self-regulate attention and carefully weigh choices, and it is these features of impaired decision-making in the context of stress that is thought to explain greater risk-taking behavior.

Assessing Risk and Decision-Making

To investigate how situations of heightened stress and arousal impact decision-making, and specifically risk-taking propensity (i.e., "a behavioral tendency to take risks in response to cues for potential reward in spite of some probability for undesirable results", MacPherson et al. 2010, pg. 332; similar to "risk preference" in Defoe et al. 2015), researchers have used performance-based tasks (also referred to as "experienced-based"; Rosenbaum et al. 2018) that can be administered in a laboratory setting. Performance-based tasks have been shown to be better at detecting differences in risk behavior between age groups compared to tasks using descriptions of hypothetical situations, potentially because performance-based tasks are more ecologically-valid to approximate decision-making in states of heightened arousal (Rosenbaum et al. 2018). An example of this type of task is the Balloon Analogue Risk Task (BART; Lejuez

et al. 2007; Lejuez et al. 2003), which has been described as a dynamic gambling task measuring risk-taking propensity and “hot” decision-making—that is, decision-making within the context of increased arousal as a result of receiving immediate feedback about gains and losses (Defoe et al. 2015; Buelow and Blaine 2015). In this task, when participants inflate a balloon, they earn money per pump. They must decide whether to continue inflating the balloon, which earns them money that they could lose if it pops (i.e., a choice with an uncertain outcome), or “bank” their earnings by starting over with a new balloon (i.e., a choice with a certain outcome). BART-measured risk-taking propensity is significantly related to real-world risk-taking behavior in adolescents and personality constructs associated with substance use (e.g., sensation seeking, impulsivity), and also highlights significant differences between adolescent smokers and non-smokers (Lejuez et al. 2003; Lejuez et al. 2005; Lejuez et al. 2007).

Researchers have used performance-based risk tasks in experimental paradigms evaluating risk under varying conditions of stress, hypothesizing that stress diminishes complex decision-making abilities. Furthermore, experimental manipulations have been instrumental in understanding how context influences risk behavior, especially in adolescents. For example, the role of stress induction on adolescent risk-taking was experimentally tested in a sample of older adolescents (Johnson et al. 2012). Two groups (control and experimental) completed baseline and follow-up risk assessments using the BART (Lejuez et al. 2002); only the experimental condition experienced the stress induction—a modified stressful public speaking task. As expected, the experimental group demonstrated more follow-up risk-taking behavior. For another study, one research team developed a gambling task that operates within a “cold” decision-making context, designed to employ cognitions ostensibly devoid of emotional arousal by not providing feedback after each decision, and a “hot” decision-making context in which feedback is provided after each gamble and is meant to be more emotionally arousing. This design enabled researchers to determine that engagement in greater risk behavior on their task was contingent on the context of emotional arousal (Figner et al. 2009). Similarly, in a within-subjects design, researchers have found that adolescents’ performance on an emotionally-arousing version of a Stroop task, compared to the non-emotionally-arousing version, predicts task-based risky driving behavior (Botdorf et al. 2017). Taken together, evidence suggests adolescents should exhibit

greater risk behavior in situations of heightened emotional arousal, and that this may depend on an individual's ability to regulate their stress response.

Current Study

Despite the established link between parent-adolescent conflict and adolescent risk behaviors, the field has not yet moved toward understanding the mechanisms of this relation. Barriers to this discovery include previous methods of conflict assessment, and the design of effective assessment methods that approximate real-world circumstances. First, how conflict is defined and assessed may lead to parents and adolescents providing inaccurate responses if they do not define conflict similarly (De Los Reyes et al. 2012b). Second, although researchers often assess conflict by constructing laboratory tasks to observe parents and adolescents discussing topics that elicit conflict at home, these paradigms have been unable to reliably elicit adolescent stress responses (Gunnar et al. 2009). Without an ecologically-valid conflict task paradigm, it is difficult to investigate why parent-adolescent conflict robustly predicts negative outcomes.

Given the aforementioned potential factors that may contribute to adolescent risk behavior and the limitations of prior research, it is imperative not only to understand which factors contribute to adolescents' greater propensity for engagement in risk behaviors, but also to investigate the mechanisms by which these factors exert their influence. To date, no prior studies have addressed whether parent-adolescent conflict is a correlate of, or temporally related to, risk behaviors; therefore, a novel paradigm designed to address the question of temporality using performance-based measures is essential to determine the direction of the effect and to identify avenues of further research (e.g., Odgers et al. 2008). In the current preliminary study, we sought to investigate the link between parent-adolescent conflict and adolescent engagement in risk behavior using an experimental design and ecologically valid methods in order to test a potential mechanism. As such, we designed the current study to address limitations of previous attempts to understand the link between parent-adolescent conflict and risk behavior in the following ways. First, we conducted structured interviews separately for parents and adolescents to distinguish domains of conflict (De Los Reyes et al. 2012b). Second, we measured hostile behavior and HRV as indices of task arousal and self-regulation, respectively. Third, we used an experimental design that included random assignment to either a control condition or conflict condition of a

discussion task between parents and adolescents. Lastly, immediately following the discussion task, adolescents completed a performance-based measure of risk-taking propensity (BART youth version; Lejuez et al. 2007).

Our objectives in conducting this study were twofold. The primary objective was to determine whether there was a temporal link between conflict and risk-taking. The secondary objective was to understand the role of self-regulation within the context of stress in the hypothesized link between parent-adolescent conflict and adolescent risk-taking. First, we hypothesized that adolescents in the conflict condition of the discussion task with their parent would evidence significantly greater post-task risk-taking propensity on a performance-based measure, relative to adolescents in the control condition. Second, we predicted that the link between parent-adolescent conflict and risk-taking propensity would be explained by adolescents' physiological regulatory ability and hostile behavior (i.e., behavioral arousal). That is, we expected that HRV, a measure of self-regulatory ability, would mediate the link between conflict and risk-taking propensity, and that this effect would be stronger for adolescents exhibiting hostile behavior during the task, indicating worse ability to regulate.

Methods

Participants and recruitment. Participants were 40 adolescents between the ages of 14-17, and their parent. Dyads initially were recruited from a multiwave longitudinal study of community adolescents (see Collado et al., 2014 for recruitment details) focusing on the development of risk behavior in youths ("parent study"). At the time of our recruitment, the parent study sample was approximately 50% African American and 54% male. Research personnel affiliated with the parent study asked participants' caregivers if they were interested in participating in the present study. Interested caregivers provided contact information for research personnel affiliated with the current study to contact them, describe study procedures, and screen for eligibility. Research personnel then contacted interested, eligible caregivers to schedule a study visit with their adolescent.

Eligibility requirements for the current investigation included speaking English; understanding the consent/assent process; having an adolescent living at home without a reported history of substantial developmental, learning, psychotic disorders or cardiac conditions (for

interpretability of HRV data); and willingness to attend a study visit with both parent and adolescent present. Fifty-one parent-adolescent dyads attended the study. Inclusion and exclusion criteria resulted in a final sample of 47 parent-adolescent dyads (see Thomas et al. 2017 for further detail). An additional seven adolescents were excluded due to missing HRV data, resulting in a final sample of 40 parent-adolescent dyads. Adolescents had been enrolled in the parent study for an average of 3.53 years ($SD = 2.59$; range 1-8). Demographic characteristics of the current sample, presented by discussion condition, are provided in Table 1. Adolescents ranged in age from 14-17 (18 males and 22 females; M age = 14.95 [$SD = 1.01$]). Parents reported adolescents' ethnicity/race as African American or Black (65%); White, Caucasian American, or European (37.5%); Hispanic or Latino/a (2.5%); or Asian American (2.5%). Family ethnicity/race totals are greater than 100% because participants could select multiple ethnic/racial categories. Adults were: seven biological fathers (17.5%), 31 biological mothers (77.5%), one adoptive mother (2.5%), and one grandmother (2.5%). All caregivers reported completing at least a high-school education. According to parent-report, 20% of the families had a weekly household income of \$500 or less; 40% had a weekly income between \$501 and \$900; and 40% earned \$901 or more per week. The economic and racial background figures for our sample are consistent with the geographic area of our sampling range (U.S. Census Bureau, 2010).

Procedures. The IRB of the large Mid-Atlantic university at which the study was conducted approved all procedures. Once a family was identified for participation, study personnel explained via telephone the purpose and procedures of the study and answered all questions before scheduling a visit. At the start of their visit, families provided informed consent/assent after a thorough explanation by research staff and were assigned a participant number that was listed on all data forms. Video and audio recordings of assessments using Noldus Observer XT were taken for later behavioral coding. Parents and adolescents separately took part in a structured interview to assess dyadic conflict and identify conflict topics, and then each dyad was informed which topic—either a conflict topic or a “control” topic (plan their dream vacation)—they had been randomly assigned to complete together in a 5-minute

discussion task¹. Immediately following the discussion task, adolescents completed a performance-based risk-taking task. Participants wore heart rate (HR) monitors throughout the study. Lastly, participants' parent or caregiver completed a demographic survey.

Physiological Recording

Throughout the tasks, we took peripheral measures of adolescents' psychophysiology using ambulatory HR monitors (i.e., Polar Electro RS800CX), consistent with prior work in this age range (e.g., Anderson and Hope 2009; De Los Reyes et al. 2012a; Thomas et al. 2012). The equipment involved a watch worn on the wrist of the non-dominant hand, and a transmitter containing electrodes attached to an elastic band around their ribcage that is worn underneath clothing. After the consent/assent process, adolescents met individually with a gender-matched research assistant to obtain height, weight, and birthdate information to be programmed by staff into the watch and to learn how to apply the HR monitor. They were provided with a private changing area within the laboratory. Psychophysiology was recorded continuously as inter-beat intervals (IBI)—the time in milliseconds (ms) between consecutive heart beats—at a sampling frequency of 1000 Hz during a 5-minute baseline period and during the remainder of the study tasks.

Heart Rate Variability

The HR monitor produced a computer file containing the data for each unit of time recorded, resulting in two files (e.g., baseline period and remaining task procedures). Using Polar ProTrainer 5 software, the computer files were “cut” to reflect the time of the task for which we were interested in obtaining psychophysiological responses (e.g., baseline and discussion task). Next, the modified Polar file was converted to a text file and processed using an Excel worksheet with formulae so that IBI values less than 200 ms or greater than 1200 ms could be identified as outliers and replaced with 200 ms or 1200 ms, respectively. The IBI values were saved as a text

¹ Prior to enrolling any participants, all participant identification numbers were randomly pre-assigned to a discussion task condition—either a conflict topic or a control topic—using an online random number generator (www.graphpad.com). We used the option “randomly assign subjects to group”; the random number generator uses as a seed the time of day. The automated randomization process is as follows: 1) participants were assigned to groups nonrandomly; 2) each participant's group assignment was switched with a randomly selected participant; 3) this process occurred two more times to ensure random group assignment.

file and processed using CMetX, a software program that takes as input an IBI text file and calculates the cardiac psychophysiology indices that may be generated from one electrocardiographic source, using an optimal finite impulse response digital filter (Allen 2002; Allen et al. 2007). Because we were interested in top-down regulatory ability as indexed by HRV, we used the high-frequency HRV (HF-HRV)² from resting baseline and 5-minute task periods, a cardiac metric which has been used by other investigators in studies of regulation (Lane et al. 2013; Smith et al. 2016). HF-HRV, a more direct measure of parasympathetic control than other indices (Berntson et al. 1997; Berntson et al. 2007), is considered by some researchers to be a transdiagnostic marker of self-regulation and to represent indirect PFC activity (Beauchaine and Thayer 2015). We measured HR during a 5-minute baseline period during which adolescents sat in a chair in a room alone and were instructed to rest, as well as throughout the discussion task while adolescents were seated, as described below. During the baseline period, a research assistant entered the room to provide a cotton swab to obtain saliva for a genetic sample for an unrelated project and returned to collect it several minutes later. When processing and reviewing the data, we noticed an increase in HR that coincided with the presence of the staff member. Thus, we chose to use a two-minute segment for the baseline time period when the adolescent was alone in the room and had acclimated to the task (60 seconds to 180 seconds) but before the saliva collection began.

Measures to Address Study Aims

Assessments were focused on five domains: (1) demographics, (2) adolescent physiological self-regulation, (3) parent-adolescent conflict, (4) adolescent behavioral arousal (hostility), and (5) adolescent risk-taking propensity.

Demographics. This parent-completed survey assessed demographics including age, gender, race/ethnicity, education level, marital and employment status, and household income.

² CMetX filters the time series IBI in the .12–.40 Hz “high frequency” band and applies a log transformation to its variance, referring to this metric as the estimate of log-transformed respiratory sinus arrhythmia (RSA). Because we did not measure respiration (see also Amole et al. 2017), for clarity we refer to it as HF-HRV. The estimate of logRSA calculated using CMetX during a stressor task correlated at 0.99 for spectral power and amplitude, indicating its high overlap with high-frequency HRV (HF-HRV; Allen et al. 2007).

Adolescent physiological self-regulation. To assess whether HRV mediated the link between parent-adolescent conflict and adolescent risk-taking propensity, we measured adolescents' HRV during the discussion task as an index of physiological self-regulation. We computed the average adolescent HRV (HF-HRV) during the 5-minute segments for both the conflict condition and the control condition of the discussion task, similar to other methods used in parent-adolescent conflict tasks (Chaplin et al. 2012; see Table 2).

Parent-adolescent conflict topics. The To(may)to-To(mah)to Interview (TTI; De Los Reyes et al. 2012b) reliably and validly assesses 1) behavioral conflict about daily life topics, and 2) parent and youth perceptions of whether discrepancies exist between their beliefs about these topics. This structured interview included youth and parent versions that gather informants' reports of parent-adolescent conflict and parent-adolescent discrepant beliefs on 16 daily life topics (e.g., youth's computer time, spending time with the family). Greater detail on this measure in this sample has been provided elsewhere (De Los Reyes et al. 2012b; Thomas et al. 2017). The TTI was used in this investigation to choose the topic for adolescents randomly assigned to the conflict condition.

Discussion task. Parents and adolescents engaged in a widely used 5-minute discussion task to resolve the assigned topic (Donenberg and Weisz 1997; Gottman 1979). As described elsewhere (Thomas et al. 2017), to include factors known to elicit a stress response (unpredictability, uncontrollability, and social evaluation; Dickerson and Kemeny 2004; Gunnar et al. 2009), we modified the task such that: a) families did not know when the discussion task would occur, b) families did not choose the discussion topic, and c) families were informed that staff would be monitoring them through a two-way mirror so they did not have to keep track of time. In the between-subjects design, families randomized to the control condition ($n = 19$) were assigned the discussion topic of planning a vacation; families randomized to the conflict condition ($n = 21$) were assigned the discussion of a conflict topic, based on previously identified topics from the TTI. At the conclusion of the TTI, for families randomized to the conflict condition, the discussion topic was chosen immediately from the adolescent's TTI responses. The topic selection was prioritized along a continuum according to the level of behavioral conflict present: that is, a topic about which an adolescent reported s/he and the parent argue or

fight was chosen first, with the least desirable topic to discuss being one in which they do not argue or fight about and do not have different beliefs. This is because we expected that topics about which adolescents report that they and their parents argue or fight would elicit the greatest adolescent stress response. Moreover, a recent meta-analysis found for links between parent-adolescent conflict and poor youth psychosocial outcomes, adolescent report of conflict had a larger effect size than parent report (Weymouth et al. 2016). Once the topic was identified, a research staff member introduced the topic to the parent and adolescent, elicited a brief description of how this topic comes up for each of them, and then explained that they would like the parent and adolescent to come to a resolution on the details of the topic for 5 minutes. The research staff member left the room during the discussion task and returned after 5 minutes.

Coding of adolescent behavioral arousal. Two video cameras in the room were focused on the adolescent and the parent, respectively, resulting in two video recordings that enabled separate coding of parent and adolescent behavior. Research staff used observational methods to code conflict behaviors as an indicator of parent-adolescent conflict-related behavior. For this study, we focused on adolescent hostile behavior to index behavioral arousal during the discussion task (e.g., Ehrlich et al. 2012). Adolescent hostile behavior has been shown to be a better predictor of their own externalizing behavior, vs. parent-to-adolescent hostility (Fosco et al. 2014). The Hostile Conflict Scale of the Conflict Task Coding System, a macro coding system, was used by four trained coders (Ziv, Cassidy, & Ramos-Marcuse, 2002, unpublished manuscript). Behaviors were rated on a 7-point anchored scale (i.e., 1 to 7); higher scores indicate greater hostility. Behaviors coded as hostile included nonverbal behaviors (e.g., negative facial expressions, eye-rolling, slamming fist on table), and verbal behaviors (yelling, mocking, interrupting, and invalidating what the other person is saying).

The coders were four research assistants; the training process has been described elsewhere (Thomas et al. 2017). Forty percent of adolescent videos were randomly selected as reliability cases (i.e., assigned to two coders) to check that coders rated behaviors similarly. Coders were blind to which cases would be used for reliability prior to rating the videos. Weekly meetings were held where reliability cases were discussed and viewed. Coders provided justification for their ratings if they were discrepant from one another. For these reliability cases,

the first author made the final decision on ratings when necessary (e.g., coders disagreed, or it was clear both coders had not rated the behavior accurately). As referenced below, the hostile behavior scores are treated in these analyses as a dichotomous variable due to skewness; therefore, interrater reliability was calculated using kappa for the dichotomous variable used in analyses. For adolescent hostile behavior, kappa was 0.63, indicating substantial reliability among raters. Percentage of cases with 100% agreement was 81.25%. Means and standard deviation estimates are presented in Table 2.

Adolescent risk-taking propensity. We assessed *adolescent risk-taking propensity* using the youth version of the BART (Lejuez et al. 2007), a performance-based measure. Adolescents inflated 30 computer-generated balloons, one at a time. In this task, each pump is worth one point, but if the balloon is pumped past its explosion point, then all points accrued for that balloon are lost. The probability that any particular balloon will explode is 1/128 for the first pump, 1/127 for the second pump, and so on until the 128th pump at which point the probability is 1/1. Thus, explosion values form a normal distribution around 64 pumps (Lejuez et al. 2002). During the task, participants could stop pumping the balloon at any time prior to an explosion and allocate the accrued points to a permanent prize meter. When a balloon exploded or points were allocated to the permanent prize meter, a new balloon appeared. After completing 30 balloon trials, the position of the prize meter determined the final prize. Adolescents completed this task at baseline (“pre-task”), and then immediately after engaging in a discussion task with their parent (“post-task”), which occurred approximately one hour after pre-task BART. BART risk-taking propensity was quantified as adjusted number of pumps across balloons to account for some trials ending earlier than others (i.e., balloon explosions; Lejuez et al. 2002). Higher scores indicate greater risk-taking propensity.

Data Analysis

Overview. We used IBM SPSS version 22 to enter data and derive descriptive statistics and preliminary analyses. All hand-entered data (e.g., behavioral codes) were double-entered, compared, cleaned, and verified. Descriptive statistics were performed to check distributional assumptions and outliers. Because hostile behavior deviated from absolute values of approximately 1 for skewness and kurtosis (Tabachnick and Fidell, 1996) and to enable ease of

interpretation of the analyses, we dichotomized this variable such that “0” represented no adolescent hostile behavior during the discussion and “1” represented any hostile behavior. Prior to dichotomizing, 20 adolescents exhibited no hostility (10 in each condition) and 20 exhibited any hostility.

Moderated Mediation. To investigate the relation between experimentally manipulated parent-adolescent conflict and adolescent risk-taking propensity and whether it varied as a function of physiological and behavioral indices, we used the PROCESS method (Model 14; Hayes 2013) adapted for MPlus (Version 7.31; Stride, Gardner, Catley, & Thomas, 2015) to conduct a second-stage moderated mediation regression analysis (Edwards and Lambert 2007). Controlling for baseline risk-taking propensity (measured by pre-task BART), we used one model to test whether there was a direct effect of discussion condition (control = 0; conflict = 1) on adolescent risk-taking propensity, or if there was a conditional indirect effect through HF-HRV depending on hostile behavior during the discussion condition (see Figure 1A). The output provides an index of moderated mediation, which quantifies the linear association between the indirect effect and the hypothesized moderator of the indirect effect (Edwards and Lambert 2007; Hayes 2015). We centered HF-HRV and dichotomous adolescent hostile behavior prior to running our analysis. Our design, although a single session, meets the assumptions of temporal ordering in mediation analyses by having predictor, mediator, and outcome variables measured in sequential order at different times (Maxwell and Cole 2007).

As described in the initial results demonstrating feasibility of our modified discussion task (Thomas et al. 2017), we used dyadic data analysis to confirm that our task performed as designed: only adolescents, not parents, evidenced expressions of hostile behavior significantly related to the conflict condition. Therefore, we did not include parental variables in our analyses.

Results

Descriptive Statistics.

We report in Tables 1 and 2 the descriptive statistics for the sample by condition. At baseline, conditions did not significantly differ on demographic variables, HF-HRV, or BART performance. As previously reported, the two conditions did significantly differ on HR, providing evidence as a manipulation check that the conflict condition elicited greater adolescent

physiological arousal than the control condition (Thomas et al. 2017). Table 3 presents a correlation table by condition, controlling for pre-task BART.

Preliminary analyses.

Age and gender were not significantly related to baseline or task HF-HRV, pre- or post-BART, or dichotomized hostile behavior (p -values ranging from 0.11-0.92), and therefore were not included in further analyses. Baseline HF-HRV was not significantly related to post-task BART ($p = 0.84$) and was also not included in analyses; however, pre-task BART was related to post-task BART ($p < 0.001$); consequently, we included pre-task BART as a covariate in the analyses.

Primary Analysis.

As detailed in Table 4 and Figure 1B, adolescents randomly assigned to the conflict condition exhibited lower HF-HRV during the discussion task than adolescents in the control condition. The effect of adolescents' lower HF-HRV on greater post-task risk-taking propensity was dependent on the presence of hostile behavior. Holding pre-task risk-taking propensity and discussion condition assignment constant, among adolescents exhibiting hostile behavior, those with lower HF-HRV exhibited greater post-task risk-taking propensity.

The index of moderated mediation ("an interval estimate of the parameter of a function linking the indirect effect to values of a moderator" [Hayes, 2015, pg. 1]) was significant: a 95% bias-corrected bootstrap confidence interval (CI) based on 10,000 bootstrap samples does not include zero (index = 2.58 [CI: 0.331 to 6.900]). This indicates that the indirect effect of conflict condition on post-task risk-taking propensity through HF-HRV is contingent on the presence of hostile behavior.

The direct effect of conflict on risk-taking propensity was not significant. The direct effect represents how much two adolescents that differ by one unit in the discussion condition will differ in risk-taking propensity when holding constant HF-HRV and hostile behavior. In other words, an adolescent in the conflict condition (coded "1") exhibits 0.38 units greater risk behavior relative to an adolescent in the control condition (coded "0"). In contrast, the conditional indirect effect of discussion condition on BART risk behavior through HF-HRV conditioned on hostile behavior was significant. It represents the amount by which two

adolescents with a given value of hostile behavior that are in different discussion conditions are estimated to differ on risk-taking propensity indirectly through the discussion task's effect on HF-HRV, which in turn influences risk-taking propensity.

Secondary Analysis.

Although our primary model of interest involved hostile behavior moderating the path between HF-HRV and BART as seen in Figure 1B, we wanted to rule out that other model configurations were a better fit to the data. Therefore, we also tested a model in which hostile behavior moderated both indirect pathways (a' and b') and the direct pathway (c') between discussion condition and adolescent risk-taking propensity. Using a chi square difference test between the full model with hostile behavior regressed onto the a', b', and c' paths, and a null model indicates there is no added benefit to using the complex model ($\chi^2 [3] = 0.38, p = 0.94$), providing support for using the more parsimonious model. Specifically, we observed that the same general pattern emerged: the only significant interaction was on the hypothesized b' path; thus, we retained the more parsimonious model presented in the primary analysis section.

Discussion

Main findings

Our experimental study examined the link between parent-adolescent conflict and adolescent risk-taking propensity, whether a physiological indicator of self-regulation mediated this link, and how this effect may depend on the presence of adolescent behavioral arousal in the form of hostility during the discussion task. We hypothesized that there would be a significant association between parent-adolescent conflict and risk-taking propensity, and that this link would be explained by impaired physiological self-regulation and behavioral arousal. Using a moderated mediation analysis, we found there was no direct effect between conflict and adolescent risk-taking propensity. Rather, there was a significant conditional indirect effect, such that there was an effect of lower HF-HRV mediating the link between conflict and greater risk-taking propensity, and that this indirect effect was contingent on the presence of adolescent hostile behavior. To our knowledge, this is the first investigation to use an experimental, multi-method design to examine the link between parent-adolescent conflict and risk-taking propensity.

Our investigation had several design strengths that advance the literature on implications of parent-adolescent conflict—a form of social stress—and adolescent risk behavior. First, we accounted for the importance of contextual factors in understanding adolescent behavior by randomly assigning parent-adolescent dyads to either a conflict condition or control condition of a discussion task. This experimental manipulation enabled us to distinguish how behavior varied as a function of the presence or absence of social stress. We found that only adolescents in the conflict condition exhibited significantly greater risk-taking propensity, as mediated by HF-HRV for adolescents exhibiting hostile behavior. Second, our design using multiple measurement methods enhances the strength of the findings. Conflict topics were identified through a structured interview, self-regulatory ability was measured through HF-HRV, behavior was rated by trained coders, and risk-taking propensity was measured with a performance-based task. Third, our focus on self-regulatory ability as an explanatory factor between conflict and risk behavior is both consistent with research on adolescent vulnerability to engagement in risk behaviors as well as offers potential strategies by which to reduce risk for poor psychosocial outcomes in situations of decision-making under stress, which we will discuss. The features of our study—experimental, multiple levels of analysis that include physiology and behavior—are consistent with those recently recommended to identify cognitive and emotional factors that contribute to adolescent decision-making (Rosenbaum and Hartley 2019).

Research and Theoretical Implications

An important broader contextual factor regarding adolescent risk behavior is that during this time period, brain regions are developing at different rates. The limbic regions associated with emotion and reward develop earlier in adolescence, resulting in greater sensitivity to rewards, especially uncertain rewards, while the slower development of their PFC explains corresponding limitations in regulatory and inhibitory abilities, thereby increasing risk-taking propensity (Casey 2015; Casey et al. 2017; Galvan et al. 2006; Shulman et al. 2016). Thus, differential brain maturation is a developmental feature common to all adolescents; however, inter- and intrapersonal individual differences exist that account for frequency and intensity of engagement in risk behaviors (Johnson et al. 2012). Along those lines, including a social stress context in our investigation is important for approximating real-world situations because

although adolescents reason similarly to adults on descriptive situations of risk, they perform differently in situations of high arousal (either positively or negatively valenced; Beyth-Marom et al. 1993; Quadrel et al. 1993; Rosenbaum et al. 2018). That is, amongst adolescents, there are certain contexts that may elicit a greater arousal response that impacts decision-making. Furthermore, individual difference factors (e.g., self-regulation) likely account for which adolescents experience the most impairment in those situations, all of which is set against the backdrop of the adolescent developmental period of differential brain maturation.

Given that during adolescence reward sensitivity is heightened, it is an important factor to investigate regarding risk propensity (Galvan et al. 2006; Somerville et al. 2010; Somerville and Casey 2010). Moreover, reward sensitivity has been associated with contextual factors like acute stress (Mather and Lighthall 2012; Porcelli and Delgado 2017; Starcke and Brand 2016). Relevant to adolescent risk behavior as pointed out by Galvan and colleagues (2013), Mather and Lighthall have proposed a model accounting for decision-making in the context of acute stress (2012). They argue that acute stress makes rewards more salient, thereby enhancing learning for rewarded choices, yet impairing learning for punished choices ("stress triggers additional reward salience [STARS]"; Mather and Lighthall 2012). Importantly, whether stress is helpful or harmful to decision-making depends on the context. If there is low probability of harm, it may be beneficial; if there is a risk of harm, inability to learn from punishment could lead to negative consequences. Further, timing of measurement matters—reward sensitivity is typically greater immediately following a stressor, and becomes blunted over time (Porcelli and Delgado 2017; Starcke and Brand 2016).

Unfortunately, most risk tasks used in research are not able to disentangle the contribution of reward sensitivity (Starcke and Brand 2016); however, it is an important factor to consider given that one's ability to self-regulate when faced with a risky yet rewarding choice will impact decision-making. Our findings indicated it was adolescents in the conflict condition with less regulatory ability and exhibiting hostile behavior that had greater risk-propensity on the BART, which translates to earning more reward points. Although the low HF-HRV suggests impaired self-regulation, we cannot determine whether greater risk propensity was a consequence of inability to learn from punishment or from goal-directed pursuit of reward.

Studies that assess trial-by-trial learning/decision-making while undergoing neuroimaging are better suited to address those questions. Importantly, it is essential to consider that risk behavior occurs in situations that are negatively valenced as well, such as threat, so risk behavior is not wholly accounted for by pursuit of rewards, but rather can also be escape from aversive situations or inability to disengage from arousing stimuli (Dreyfuss et al. 2014). Therefore, it may not necessarily be only reward sensitivity that is heightened in adolescence, but more specifically that sensitivity to emotionally arousing cues is greater, suggesting the need to take into account negative situations because those can also result in propensity for risk behavior.

Parent-adolescent conflict and risk-taking.

Therefore, how and under what circumstances risk-taking propensity is measured may substantially alter research conclusions. Parent-adolescent relationship quality, especially regarding conflict, has long been associated with adolescent engagement in risk behaviors (Ary et al. 1999; Burt et al. 2003; Dmitrieva et al. 2004; Duncan et al. 1998; Klahr et al. 2011; Van Doorn et al. 2008). In fact, decreases in positive parenting from one measurement time point to the next is associated with increases over time in neural activity in the ventral striatum (associated with reward), and with increases in adolescent risk-taking propensity, as quantified by an increased BART score over time (Qu et al. 2015). The researchers hypothesized that a negative family environment may result in adolescents being more inclined to engage in risky behavior for the pursuit of rewards. Although our study design was different in that we experimentally manipulated the context of parent-adolescent interactions, the influence of parent-adolescent relationship characteristics on adolescent risk-taking propensity, and the individual difference factor (i.e., ventral striatum activity), has overlapping features with our findings.

Interestingly, we did not find a direct effect of assignment to the conflict condition on adolescent risk-taking propensity. Rather, our findings indicate that the adolescents with less regulatory ability in the context of high arousal (e.g., conflict condition, hostile behavior) exhibit greater risk-taking propensity. Thus, we found that contextual variation is a distinguishing factor in the expression of risk behaviors— after exposure to differing social contexts, adolescents make different decisions evaluating choices with certain and uncertain outcomes (e.g., risk)—

and that individual differences of regulatory ability and arousal explain the link between conflict and risk-taking propensity. In sum, although adolescents are generally more vulnerable to engaging in risk behavior than other age groups due to their differential brain development, it is situations that require adolescents to make calculated decisions in the context of stress that may highlight this vulnerability even more than neutral situations. In other words, both contextual factors and individual difference factors are important when investigating mechanisms of youth psychopathology and maladjustment (Steege et al. 2017).

Regulatory ability. Adolescents have greater sensitivity to situations of heightened arousal, rewards, and emotion, which has been shown to be directly related to their inability to self-regulate in those contexts (Dreyfuss et al. 2014). In the current study, we measured self-regulatory ability with a physiological marker, HF-HRV, a form of HRV that represents parasympathetic response. The parasympathetic branch of the autonomic nervous system acts as the “brake” to the more arousal-related sympathetic nervous system, playing an integral role in maintaining homeostasis (Berntson et al. 2007; Thomas et al. 2012). Results from our investigation suggest that the link between parent-adolescent conflict and risk-taking propensity is explained by impaired self-regulatory ability, which is consistent with theories and research that exposure to stress impairs decision-making (Starcke and Brand 2016) by limiting one’s ability to process a full range of contextual stimuli (Porcelli and Delgado 2009; Wichary et al. 2016).

Our findings that the indirect effect of lower HF-HRV on the link between conflict and greater risk-taking propensity depends on the presence of hostile behavior appears to indicate that adolescents with less self-regulation ability were those that exhibited hostile behavior, a form of arousal, during the discussion task. These findings are consistent with other research linking self-regulation with risk-taking behavior. For example, in a cross-sectional study based on survey data from adolescent participants, greater self-reported self-restraint (a construct similar to self-regulation ability) was associated with less risk-taking behavior (Curry and Youngblade 2006). Furthermore, self-reported anger (i.e., negatively-valenced affective arousal similar to our measurement of hostile behavior) moderated the relation between self-reports of self-restraint and engagement in risk-behavior, but only for adolescents with low self-restraint,

which was similar to our findings that lower self-regulation leading to greater risk-taking propensity depended on the presence of hostile behavior. Relatedly, in their experimental study, Johnson and colleagues (2012) found that although adolescents in the stress condition (vs. control condition) exhibited greater risk-taking on the BART, risk characteristics measured at baseline explained this behavior, with adolescents characterized as conservative exhibiting the least risk propensity (even under stress), and adolescents categorized as impulsive, representing poor self-regulatory ability, exhibiting the greatest. Although not a study on adolescents, other researchers also found an indirect effect of a stress manipulation on task-based risk-taking, such that impaired cognitive processing mediated this link (Simonovic et al. 2018). Therefore, self-regulatory ability is an important individual difference factor related to situations of social stress, as well as to risk-taking behavior in general and during adolescence specifically, and may provide potential avenues of strategies to prevent adverse outcomes in adolescents, as we will discuss.

Implications for parent-adolescent conflict. The link between parent-adolescent conflict and risk behavior (i.e., externalizing behavior, substance use) has both genetic and environmental contributions (Burt and Klump 2014; Burt et al. 2003; Burt et al. 2005; Klahr et al. 2011) and is significantly related to poor psychosocial outcomes in general (Laursen and Hafen 2010; Weymouth et al. 2016). Negative affect, a component of hostility, is also a significant contributor to this maladjustment (Laursen et al. 2016; Weymouth et al. 2016). Furthermore, increased arousal in the context of parent-adolescent conflict interactions has been linked to alcohol use (Chaplin et al. 2012). Much less is known about the mechanism of this link—whether parent-adolescent conflict shares an underlying vulnerability with expressions of externalizing behavior (e.g., impulsivity), or whether there is a causal relation—which is a barrier to effectively weakening this link through targeted strategies. Our study design involving experimental manipulation of conflict, random assignment, and temporal ordering of discussion task and then subsequent measurement of risk-taking propensity enables us to infer from our results that there is a temporal relation between conflict and adolescent risk-taking. Understanding this mechanism underlying the association between parent-adolescent conflict and adolescent risk-taking propensity has the benefit of enabling targeted recommendations to

prevent situations of stress devolving into decisions that may lead to adverse adolescent outcomes.

First, although we will primarily address adolescent-focused strategies because adolescents are responsible for their own self-regulation and subsequent behavior, it is important to note parent-adolescent conflict is an interactional process, and as such, may require a more systemic approach (i.e., family therapy techniques). Indeed, psychosocial interventions and prevention programs may be optimal, albeit overlooked, methods by which to target environmental risk factors as previously pointed out (Crowell et al. 2013). It has been theorized that parent-adolescent conflict arises from different interpretations of adolescent behavior: adolescents perceive their behavior as a right to assert their individuality, whereas parents' may view adolescents' behavior in a more collectivist fashion as violating a social contract (Branje 2018; Smetana 1989). Therefore, family therapy techniques could help parents and adolescents take the others' perspective to reduce the negative attributions they may be putting on behavior, thereby decreasing the emotional intensity of the conflict. This strategy could be considered a form of interpersonal reappraisal, by having parents and adolescents reframe how they view the conflict.

Second, decreasing adolescents' behavioral arousal (i.e., hostility) is also an important step toward reducing the intensity of parent-adolescent conflict and mitigating the potential harm that may come from associated risk-taking propensity. Indeed, greater adolescent hostility is related to more externalizing behavior over time (Fosco et al. 2014; Glatz et al. 2019), which researchers hypothesize may be due to adolescents' hostility influencing parents' interaction style as well, negatively impacting bidirectional family relationships (Glatz et al. 2019). For more aversive, chronic conflict, intervention strategies that involve parents or other caregivers are critical to changing both individual behavior and the environment (Hartnett et al. 2017). Reducing this interpersonal negative affect is also an important component of family therapy. Specifically, Functional Family Therapy, an effective, evidence-based treatment for adolescent externalizing behaviors, emphasizes negativity reduction between parents and adolescents as the first step of treatment, given that it is hypothesized family members will not be able to agree on

behavior change strategies until the negativity is reduced (Alexander and Parsons 1982; Hartnett et al. 2017).

Third, adolescent risk-taking propensity may originate as a form of maladaptive coping in response to stressors. Qu and colleagues (2015) hypothesized that their findings of reduced positive parenting over time relating to increased adolescent risk-taking propensity may be explained by adolescents seeking other forms of rewarding experiences to balance the lack of support they may experience with their family, leading to more risk-taking behavior. One form of maladaptive coping behavior relevant to risk-taking propensity is substance use, a behavior with which the BART performance has been shown to be associated (Lejuez et al. 2003; Lejuez et al. 2005; Lejuez et al. 2007). It is also possible that our paradigm and findings relate to other types of maladaptive outcomes for adolescents, including internalizing disorders and related risk behaviors (e.g., suicidal behavior, non-suicidal self-injury), given that parent-adolescent conflict may also be a transdiagnostic risk factor for youth psychopathology (Weymouth et al. 2016), and low HRV has previously been suggested as a general indicator of psychopathology, similar to the *p* factor proposed by Caspi and colleagues (Beauchaine and Thayer 2015; Caspi et al. 2014). Future studies would benefit from adapting our paradigm to other situations of youth psychopathology to investigate whether the mechanism generalizes.

There are several strategies adolescents can use to manage their stress that may limit their coping via risk behaviors, which may have short-term benefits yet potential for long-term negative consequences. For example, strategies such as focusing on what adolescents can control in situations of stress, how they can increase their ability to practice and exert self-control, and using effective communication strategies to reduce aversive conflict proactively, similarly to other behavioral regulation recommendations in psychiatric disorders of externalizing or dysregulation (e.g., ADHD treatment strategies or dialectical behavior therapy), may also be relevant to situations of maladaptive parent-adolescent conflict that are perceived as stressful. Adolescents may benefit from increasing their awareness of both what their decision-making style is under stress and what situations they perceive as stressful (Johnson et al. 2012) so that they can identify alternative coping strategies and practice those ahead of when they are needed. Lastly, it may help adolescents to use reappraisal strategies to reframe the arousal they feel

during stressful situations as an opportunity to implement coping strategies, rather than experiencing the feeling of being under threat, in order to be motivated to use coping strategies and to reduce negative affect that can be associated with stress (Jamieson et al. 2018). In sum, the benefit to our results is they align with options of various levels by which one can intervene to potentially avert negative consequences from parent-adolescent conflict.

Limitations

Despite its strengths, our investigation has several limitations. First, as other authors have discussed (Wolff and Crockett 2011), some performance-based tasks like BART do not have the same real-world consequences as engaging in actual risk behavior, and therefore do not approximate life-threatening consequences. Yet experience-based tasks like BART appear more sensitive to contextual variation compared to survey measures asking about risk behavior using hypothetical descriptions (Rosenbaum et al. 2018). Second, we did not measure respiration as part of our physiological assessment. Researchers are mixed on the feasibility of this measurement, especially during tasks involving speech and because covarying out respiration may remove meaningful variance related to neural influences (Amole et al. 2017; Laborde et al. 2017). CMetX requires only the IBI data source to calculate the HF-HRV estimate we used. Additionally, we do not have reason to believe our two conditions differed on speech because both conditions were given a topic to resolve and they were being observed during the task. Indicating that our results were not due to artifacts by not controlling respiration, we also ran the same moderated mediation model using HR instead of HF-HRV, and we found the same significant results, albeit in the opposite direction due to a stress response indexed by HR arousal being a greater value, while an HF-HRV-indexed stress response is a lower value. Third, as mentioned in the Methods section, our baseline HF-HRV measurement was less than ideal due to having a staff member interrupt during this period. This limits our ability to understand within-subject variability, given that we were only able to retain a mid-point 2-minute sample, rather than 5 minutes. Finally, our sample size is also a limitation. This preliminary analysis in a community sample of adolescents using behavioral and psychophysiological indices provides proof of concept for the potential mechanism by which parent-adolescent conflict is linked to adolescent risk-taking propensity and warrants replication in a larger sample.

Concluding Comments

Using an experimental manipulation, we found an indirect effect of parent-adolescent conflict on subsequent risk-taking propensity, such that lower HRV—representing impaired regulation—mediated this relation, and this indirect effect was dependent on hostile behavior. Therefore, there is a proximal effect of conflict on risk behavior, which is explained by reduced regulatory ability in the context of behavioral arousal. These findings appear to support theories that decision-making within the context of increased stress is impaired due to decreased ability to exert top-down regulatory control over physiology and behavior, which may lead to an increase in risk behaviors. Because adolescents are already vulnerable to engagement in risk behavior, it would be beneficial for there to be greater awareness of situations in which adolescents may experience more stress and dysregulation; to facilitate individualized recognition of emotional, behavioral, and physiological signs of increased stress; and to have knowledge of strategies for effective coping and increasing regulatory ability (e.g., calm breathing).

Compliance with Ethical Standards

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Ethical approval: All procedures performed in studies involving human participants were in

accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all adult participants included in the study. Assent was obtained from all adolescent participants included in the study.

References

- Alexander, J. F., & Parsons, B. V. (1982). *Functional family therapy: Principles and procedures*. Carmel, CA: Brooks/Cole.
- Allen, J. J. B. (2002). Calculating metrics of cardiac chronotropy: A pragmatic overview. *Psychophysiology*, 39, S18-S18.
- Allen, J. J. B., Chambers, A. S., & Towers, D. N. (2007). The many metrics of cardiac chronotropy: A pragmatic primer and a brief comparison of metrics. *Biological Psychology*, 74, 243-262, doi:10.1016/j.biopsycho.2006.08.005.
- Amole, M. C., Cyranowski, J. M., Wright, A. G. C., & Swartz, H. A. (2017). Depression impacts the physiological responsiveness of mother-daughter dyads during social interaction. *Depression and Anxiety*, 34, 118-126, doi:10.1002/da.22595.
- Anderson, E. R., & Hope, D. A. (2009). The relationship among social phobia, objective and perceived physiological reactivity, and anxiety sensitivity in an adolescent population. *Journal of Anxiety Disorders*, 23, 18-26, doi:10.1016/j.janxdis.2008.03.011.
- Arnsten, A. F. T. (1999). Development of the cerebral cortex: XIV. Stress impairs prefrontal cortical function. *Journal of the American Academy of Child & Adolescent Psychiatry*, 38, 220-222, doi:10.1097/00004583-199902000-00024.
- Arnsten, A. F. T., Raskind, M. A., Taylor, F. B., & Connor, D. F. (2015). The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. *Neurobiology of Stress*, 1, 89-99.
- Ary, D. V., Duncan, T. E., Biglan, A., Metzler, C. W., Noell, J. W., & Smolkowski, K. (1999). Development of adolescent problem behavior. *Journal of Abnormal Child Psychology*, 27, 141-150, doi:10.1023/a:1021963531607.
- Beauchaine, T. P., & Thayer, J. F. (2015). Heart rate variability as a transdiagnostic biomarker of psychopathology. *International Journal of Psychophysiology*, 98, 338-350, doi:10.1016/j.ijpsycho.2015.08.004.
- Berntson, G. G., Bigger, J. T., Jr., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., et al. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology*, 34, 623-648, doi:10.1111/j.1469-8986.1997.tb02140.x.

- Berntson, G. G., Quigley, K. S., & Lozano, D. (2007). Cardiovascular psychophysiology. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of Psychophysiology* (3rd ed.). (pp. 182-210). New York, NY US: Cambridge University Press.
- Beyth-Marom, R., Austin, L., Fischhoff, B., Palmgren, C., & Jacobs-Quadrel, M. (1993). Perceived consequences of risky behaviors: Adults and adolescents. *Developmental Psychology*, 29, 549-563, doi:10.1037/0012-1649.29.3.549.
- Botdorf, M., Rosenbaum, G. M., Patrianakos, J., Steinberg, L., & Chein, J. M. (2017). Adolescent risk-taking is predicted by individual differences in cognitive control over emotional, but not non-emotional, response conflict. *Cognition and Emotion*, 31, 972-979, doi:10.1080/02699931.2016.1168285.
- Branje, S. (2018). Development of Parent-Adolescent Relationships: Conflict Interactions as a Mechanism of Change. *Child Development Perspectives*, 12, 171-176, doi:10.1111/cdep.12278.
- Buehler, C. (2006). Parents and peers in relation to early adolescent problem behavior. *Journal of Marriage and Family*, 68, 109-124, doi:10.1111/j.1741-3737.2006.00237.x.
- Buelow, M. T., & Blaine, A. L. (2015). The assessment of risky decision making: a factor analysis of performance on the Iowa Gambling Task, Balloon Analogue Risk Task, and Columbia Card Task. *Psychological Assessment*, 27, 777-785, doi:10.1037/a0038622.
- Burt, S. A., & Klump, K. L. (2014). Parent-child conflict as an etiological moderator of childhood conduct problems: An example of a 'bioecological' gene-environment interaction. *Psychological Medicine*, 44, 1065-1076, doi:10.1017/S0033291713001190.
- Burt, S. A., Krueger, R. F., McGue, M., & Iacono, W. (2003). Parent-child conflict and the comorbidity among childhood externalizing disorders. *Archives of General Psychiatry*, 60, 505-513, doi:10.1001/archpsyc.60.5.505.
- Burt, S. A., McGue, M., Krueger, R. F., & Iacono, W. G. (2005). How are parent-child conflict and childhood externalizing symptoms related over time? Results from a genetically informative cross-lagged study. *Development and Psychopathology*, 17, 145-165, doi:10.1017/S095457940505008X.

- Casey, B. J. (2015). Beyond simple models of self-control to circuit-based accounts of adolescent behavior. *Annual Review of Psychology*, 66, 295-319, doi:10.1146/annurev-psych-010814-015156.
- Casey, B. J., Heller, A. S., Gee, D. G., & Cohen, A. O. (2017). Development of the emotional brain. *Neuroscience Letters*, doi:10.1016/j.neulet.2017.11.055.
- Caspi, A., Houts, R. M., Belsky, D. W., Goldman-Mellor, S. J., Harrington, H., Israel, S., et al. (2014). The p Factor: One General Psychopathology Factor in the Structure of Psychiatric Disorders? *Clinical Psychological Science*, 2, 119-137, doi:10.1177/2167702613497473.
- Chaplin, T. M., Sinha, R., Simmons, J. A., Healy, S. M., Mayes, L. C., Hommer, R. E., et al. (2012). Parent-adolescent conflict interactions and adolescent alcohol use. *Addictive Behaviors*, 37, 605-612, doi:10.1016/j.addbeh.2012.01.004.
- Chida, Y., & Hamer, M. (2008). Chronic Psychosocial Factors and Acute Physiological Responses to Laboratory-Induced Stress in Healthy Populations: A Quantitative Review of 30 Years of Investigations. *Psychological Bulletin*, 134, 829-885, doi:10.1037/a0013342.
- Chida, Y., & Steptoe, A. (2009). The Association of Anger and Hostility With Future Coronary Heart Disease A Meta-Analytic Review of Prospective Evidence. *Journal of the American College of Cardiology*, 53(11), 936-946, doi:10.1016/j.jacc.2008.11.044.
- Crowell, S. E., Baucom, B. R., McCauley, E., Potapova, N. V., Fitelson, M., Barth, H., et al. (2013). Mechanisms of contextual risk for adolescent self-injury: Invalidation and conflict escalation in mother-child interactions. *Journal of Clinical Child and Adolescent Psychology*, 42, 467-480, doi:10.1080/15374416.2013.785360.
- Curry, L. A., & Youngblade, L. M. (2006). Negative affect, risk perception, and adolescent risk behavior. *Journal of Applied Developmental Psychology*, 27, 468-485, doi:10.1016/j.appdev.2006.06.001.
- De Los Reyes, A., Aldao, A., Thomas, S. A., Daruwala, S., Swan, A. J., Van Wie, M., et al. (2012a). Adolescent self-reports of social anxiety: Can they disagree with objective

- psychophysiological measures and still be valid? *Journal of Psychopathology and Behavioral Assessment*, 34, 308-322, doi:10.1007/s10862-012-9289-2.
- De Los Reyes, A., Thomas, S. A., Swan, A. J., Ehrlich, K. B., Reynolds, E. K., Suarez, L., et al. (2012b). "It depends on what you mean by 'Disagree'": Differences between parent and child perceptions of parent-child conflict. *Journal of Psychopathology and Behavioral Assessment*, 34, 293-307, doi:10.1007/s10862-012-9288-3.
- Defoe, I. N., Dubas, J. S., Figner, B., & van Aken, M. A. G. (2015). A Meta-Analysis on Age Differences in Risky Decision Making: Adolescents Versus Children and Adults. *Psychological Bulletin*, 141, 48-84, doi:10.1037/a0038088.
- Derryberry, D., & Tucker, D. M. (1994). Motivating the focus of attention. In P. Niedenthal, & S. Kitayama (Eds.), *The heart's eye: Emotional influences in perception and attention* (pp. 167–196). San Diego, CA: Academic Press.
- Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, 130, 355-391, doi:10.1037/0033-2909.130.3.355.
- Dmitrieva, J., Chen, C. S., Greenberger, E., & Gil-Rivas, V. (2004). Family relationships and adolescent psychosocial outcomes: Converging findings from Eastern and Western cultures. *Journal of Research on Adolescence*, 14, 425-447, doi:10.1111/j.1532-7795.2004.00081.x.
- Donenberg, G. R., & Weisz, J. R. (1997). Experimental task and speaker effects on parent-child interactions of aggressive and depressed/anxious children. *Journal of Abnormal Child Psychology*, 25, 367-387, doi:10.1023/A:1025733023979.
- Dreyfuss, M., Caudle, K., Drysdale, A. T., Johnston, N. E., Cohen, A. O., Somerville, L. H., et al. (2014). Teens Impulsively React rather than Retreat from Threat. *Developmental Neuroscience*, 36, 220-227, doi:10.1159/000357755.
- Duncan, S. C., Duncan, T. E., Biglan, A., & Ary, D. (1998). Contributions of the social context to the development of adolescent substance use: A multivariate latent growth modeling approach. *Drug and Alcohol Dependence*, 50, 57-71, doi:10.1016/s0376-8716(98)00006-4.

- Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review*, 66, 183-201, doi:10.1037/h0047707.
- Edwards, J. R., & Lambert, L. S. (2007). Methods for integrating moderation and mediation: A general analytical framework using moderated path analysis. *Psychological Methods*, 12, 1-22, doi:10.1037/1082-989x.12.1.1.
- Ehrlich, K. B., Dykas, M. J., & Cassidy, J. (2012). Tipping points in adolescent adjustment: Predicting social functioning from adolescents' conflict with parents and friends. *Journal of Family Psychology*, 26, 776-783, doi:10.1037/a0029868.
- Evans, J. S. (2003). In two minds: dual-process accounts of reasoning. *Trends in Cognitive Sciences*, 7(10), 454-459.
- 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, 709-730, doi:10.1037/a0014983
- Fosco, G. M., Lippold, M., & Feinberg, M. E. (2014). Interparental boundary problems, parent-adolescent hostility, and adolescent-parent hostility: A family process model for adolescent aggression problems. *Couple and Family Psychology: Research and Practice*, 3, 141 - 155.
- Galvan, A., Hare, T. A., Parra, C. E., Penn, J., Voss, H., Glover, G., et al. (2006). Earlier development of the accumbens relative to orbitofrontal cortex might underlie risk-taking behavior in adolescents. *The Journal of Neuroscience*, 26, 6885-6892, doi:10.1523/JNEUROSCI.1062-06.2006.
- Galvan, A., & Rahdar, A. (2013). The neurobiological effects of stress on adolescent decision making. *Neuroscience*, 249, 223-231, doi:10.1016/j.neuroscience.2012.09.074.
- Glatz, T., Lippold, M., Jensen, T. M., Fosco, G. M., & Feinberg, M. E. (2019). Hostile Interactions in the Family: Patterns and Links to Youth Externalizing Problems. *The Journal of Early Adolescence*, 0(0), 0272431618824718, doi:10.1177/0272431618824718.

- Gottman, J. M. (1979). *Marital interaction: Experimental investigations*. New York: Academic Press.
- Gunnar, M. R., Talge, N. M., & Herrera, A. (2009). Stressor paradigms in developmental studies: What does and does not work to produce mean increases in salivary cortisol. *Psychoneuroendocrinology*, *34*, 953-967, doi:10.1016/j.psyneuen.2009.02.010.
- Hartnett, D., Carr, A., Hamilton, E., & O'Reilly, G. (2017). The effectiveness of functional family therapy for adolescent behavioral and substance misuse problems: A meta-analysis. *Family Process*, *56*, 607-619, doi:10.1111/famp.12256.
- Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (Methodology in the social sciences). New York, NY, US: Guilford Press.
- Hayes, A. F. (2015). An Index and Test of Linear Moderated Mediation. *Multivariate Behavioral Research*, *50*, 1-22, doi:10.1080/00273171.2014.962683.
- Hermans, E. J., Henckens, M. J., Joels, M., & Fernandez, G. (2014). Dynamic adaptation of large-scale brain networks in response to acute stressors. *Trends Neurosci*, *37*, 304-314, doi:10.1016/j.tins.2014.03.006.
- Holzman, J. B., & Bridgett, D. J. (2017). Heart rate variability indices as bio-markers of top-down self-regulatory mechanisms: A meta-analytic review. *Neuroscience and Biobehavioral Reviews*, *74*, 233-255, doi:10.1016/j.neubiorev.2016.12.032.
- Jamieson, J. P., & Mendes, W. B. (2016). Social stress facilitates risk in youths. *Journal of Experimental Psychology-General*, *145*, 467-485, doi:10.1037/xge0000147.
- Jamieson, J. P., Hangen, E. J., Lee, H. Y., & Yeager, D. S. (2018). Capitalizing on Appraisal Processes to Improve Affective Responses to Social Stress. *Emotion Review*, *10*, 30-39, doi:10.1177/1754073917693085.
- Johnson, S. B., Dariotis, J. K., & Wang, C. (2012). Adolescent risk taking under stressed and nonstressed conditions: Conservative, calculating, and impulsive types. *Journal of Adolescent Health*, *51*, S34-S40, doi:10.1016/j.jadohealth.2012.04.021.

- Kann, L., McManus, T., Harris, W. A., Shanklin, S. L., Flint, K. H., Hawkins, J., et al. (2016). Youth Risk Behavior Surveillance - United States, 2015. *MMWR Surveill Summ*, 65, 1-174, doi:10.15585/mmwr.ss6506a1.
- Kemp, A. H., Koenig, J., & Thayer, J. F. (2017). From psychological moments to mortality: A multidisciplinary synthesis on heart rate variability spanning the continuum of time. *Neuroscience & Biobehavioral Reviews*, 83, 547-567, doi:10.1016/j.neubiorev.2017.09.006.
- Klahr, A. M., Rueter, M. A., McGue, M., Iacono, W. G., & Burt, A. S. (2011). The relationship between parent-child conflict and adolescent antisocial behavior: Confirming shared environmental mediation. *Journal of Abnormal Child Psychology*, 39, 683-694, doi:10.1007/s10802-011-9505-7.
- Laborde, S., Mosley, E., & Thayer, J. F. (2017). Heart Rate Variability and Cardiac Vagal Tone in Psychophysiological Research - Recommendations for Experiment Planning, Data Analysis, and Data Reporting. *Frontiers in Psychology*, 8, 213, doi:10.3389/fpsyg.2017.00213.
- Lane, R. D., Weidenbacher, H., Smith, R., Fort, C., Thayer, J. F., & Allen, J. J. (2013). Subgenual anterior cingulate cortex activity covariation with cardiac vagal control is altered in depression. *Journal of Affective Disorders*, 150, 565-570, doi:10.1016/j.jad.2013.02.005.
- Laursen, B., Coy, K. C., & Collins, W. A. (1998). Reconsidering changes in parent-child conflict across adolescence: A meta-analysis. *Child Development*, 69, 817-832, doi:10.2307/1132206.
- Laursen, B., DeLay, D., Richmond, A., & Rubin, K. H. (2016). Youth negative affect attenuates associations between compromise and mother-adolescent conflict outcomes. *Journal of Child and Family Studies*, 25, 1110-1118, doi:10.1007/s10826-015-0288-2.
- Laursen, B., & Hafen, C. A. (2010). Future directions in the study of close relationships: Conflict is bad (except when it's not). *Social Development*, 19, 858-872, doi:10.1111/j.1467-9507.2009.00546.x.

- Lejuez, C. W., Aklin, W., Daughters, S., Zvolensky, M., Kahler, C., & Gwadz, M. (2007). Reliability and validity of the youth version of the Balloon Analogue Risk Task (BART-Y) in the assessment of risk-taking behavior among inner-city adolescents. *Journal of Clinical Child and Adolescent Psychology*, 36, 106-111, doi:10.1207/s15374424jccp3601_11.
- 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, 71-79, doi:10.1080/14622200412331328484.
- Lejuez, C. W., Aklin, W. M., Jones, H. A., Richards, J. B., Strong, D. R., Kahler, C. W., et al. (2003). The Balloon Analogue Risk Task (BART) differentiates smokers and nonsmokers. *Experimental and Clinical Psychopharmacology*, 11, 26-33, doi:10.1037/1064-1297.11.1.26.
- Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., et al. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, 8, 75-84, doi:10.1037/1076-898x.8.2.75.
- Liston, C., McEwen, B. S., & Casey, B. J. (2009). Psychosocial stress reversibly disrupts prefrontal processing and attentional control. *Proceedings of the National Academy of Sciences of the United States of America*, 106, 912-917, doi:10.1073/pnas.0807041106.
- Luecken, L. J., & Roubinov, D. S. (2012). Hostile behavior links negative childhood family relationships to heart rate reactivity and recovery in young adulthood. *Int J Psychophysiol*, 84, 172-179, doi:10.1016/j.ijpsycho.2012.02.003.
- MacPherson, L., Reynolds, E. K., Daughters, S. B., Wang, F., Cassidy, J., Mayes, L. C., et al. (2010). Positive and negative reinforcement underlying risk behavior in early adolescents. *Prevention Science*, 11, 331-342, doi:10.1007/s11121-010-0172-7.
- Maier, S. U., & Hare, T. A. (2017). Higher Heart-Rate Variability Is Associated with Ventromedial Prefrontal Cortex Activity and Increased Resistance to Temptation in Dietary Self-Control Challenges. *Journal of Neuroscience*, 37, 446-455, doi:10.1523/jneurosci.2815-16.2017.

- Mather, M., & Lighthall, N. R. (2012). Both Risk and Reward are Processed Differently in Decisions Made Under Stress. *Current Directions in Psychological Science*, 21, 36-41, doi:10.1177/0963721411429452.
- Maxwell, S. E., & Cole, D. A. (2007). Bias in cross-sectional analyses of longitudinal mediation. *Psychological Methods*, 12, 23-44, doi:10.1037/1082-989x.12.1.23.
- Odgers, C. L., Caspi, A., Nagin, D. S., Piquero, A. R., Slutske, W. S., Milne, B. J., et al. (2008). Is it important to prevent early exposure to drugs and alcohol among adolescents? *Psychological Science*, 19, 1037-1044, doi:10.1111/j.1467-9280.2008.02196.x.
- Porcelli, A. J., & Delgado, M. R. (2009). Acute Stress Modulates Risk Taking in Financial Decision Making. *Psychological Science*, 20, 278-283, doi:10.1111/j.1467-9280.2009.02288.x.
- Porcelli, A. J., & Delgado, M. R. (2017). Stress and decision making: effects on valuation, learning, and risk-taking. *Current Opinion in Behavioral Sciences*, 14, 33-39, doi:10.1016/j.cobeha.2016.11.015.
- Qin, S., Hermans, E. J., van Marle, H. J. F., Luo, J., & Fernández, G. (2009). Acute psychological stress reduces working memory-related activity in the dorsolateral prefrontal cortex. *Biological Psychiatry*, 66, 25-32, doi:10.1016/j.biopsych.2009.03.006.
- Qu, Y., Fuligni, A. J., Galvan, A., & Telzer, E. H. (2015). Buffering effect of positive parent-child relationships on adolescent risk taking: A longitudinal neuroimaging investigation. *Dev Cogn Neurosci*, 15, 26-34, doi:10.1016/j.dcn.2015.08.005.
- Quadrel, M. J., Fischhoff, B., & Davis, W. (1993). Adolescent (in)vulnerability. *American Psychologist*, 48, 102-116, doi:10.1037/0003-066x.48.2.102.
- Rosenbaum, G. M., & Hartley, C. A. (2019). Developmental perspectives on risky and impulsive choice. *Philosophical Transactions of the Royal Society B-Biological Sciences*, 374(1766), 13, doi:10.1098/rstb.2018.0133.
- Rosenbaum, G. M., Venkatraman, V., Steinberg, L., & Chein, J. M. (2018). The influences of described and experienced information on adolescent risky decision making. *Developmental Review*, 47, 23-43, doi:10.1016/j.dr.2017.09.003.

- Shulman, E. P., Smith, A. R., Silva, K., Icenogle, G., Duell, N., Chein, J., et al. (2016). The dual systems model: Review, reappraisal, and reaffirmation. *Developmental Cognitive Neuroscience*, 17, 103-117, doi:10.1016/j.dcn.2015.12.010.
- Simonovic, B., Stupple, E. J. N., Gale, M., & Sheffield, D. (2018). Performance Under Stress: An Eye-Tracking Investigation of the Iowa Gambling Task (IGT). *Front Behav Neurosci*, 12, 217, doi:10.3389/fnbeh.2018.00217.
- Smetana, J. G. (1989). Adolescents' and parents' reasoning about actual family conflict. *Child Development*, 60, 1052-1067, doi:10.2307/1130779.
- Smith, R., Allen, J. J. B., Thayer, J. F., & Lane, R. D. (2016). Regional Frontal Lobe Response Magnitudes During Affective Shifting Covary With Resting Heart Rate Variability in Healthy Volunteers A Preliminary Report. *Journal of Psychophysiology*, 30, 165-175, doi:10.1027/0269-8803/a000166.
- Somerville, L. H., & Casey, B. J. (2010). Developmental neurobiology of cognitive control and motivational systems. *Current Opinion in Neurology*, 20, 236-241, doi:10.1016/j.conb.2010.01.006.
- 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, 124-133, doi:10.1016/j.bandc.2009.07.003.
- Spear, L. P. (2011). Rewards, aversions and affect in adolescence: Emerging convergences across laboratory animal and human data. *Developmental Cognitive Neuroscience*, 1, 390-403, doi:10.1016/j.dcn.2011.08.001.
- Starcke, K., & Brand, M. (2016). Effects of stress on decisions under uncertainty: A meta-analysis. *Psychological Bulletin*, 142, 909-933, doi:10.1037/bul0000060.
- Steeger, C. M., Cook, E. C., & Connell, C. M. (2017). The interactive effects of stressful family life events and cortisol reactivity on adolescent externalizing and internalizing behaviors. *Child Psychiatry & Human Development*, 48, 225-234, doi:10.1007/s10578-016-0635-6.
- Stride, C. B., Gardner, S., Catley, N., & Thomas, F. (2015). Mplus code for mediation, moderation, and moderated mediation models.
<http://www.offbeat.group.shef.ac.uk/FIO/mplusmedmod.htm>

- Tabachnick, B. G., & Fidell, L. S. (1996). *Using multivariate statistics., 3rd ed.* New York, NY: HarperCollins Publishers.
- Thayer, J. F., & Lane, R. D. (2009). Claude Bernard and the heart-brain connection: Further elaboration of a model of neurovisceral integration. *Neuroscience and Biobehavioral Reviews*, 33, 81-88, doi:10.1016/j.neubiorev.2008.08.004.
- Thomas, S. A., Aldao, A., & De Los Reyes, A. (2012). Implementing clinically feasible psychophysiological measures in evidence-based assessments of adolescent social anxiety. *Professional Psychology-Research and Practice*, 43, 510-519, doi:10.1037/a0029183.
- Thomas, S. A., Wilson, T., Jain, A., Deros, D. E., Um, M., Hurwitz, J., et al. (2017). Toward Developing Laboratory-Based Parent-Adolescent Conflict Discussion Tasks that Consistently Elicit Adolescent Conflict-Related Stress Responses: Support from Physiology and Observed Behavior. *Journal of Child and Family Studies*, 26, 3288-3302, doi:10.1007/s10826-017-0844-z.
- U.S. Census Bureau. (2010). State and county quickfacts: Washington, DC. Retrieved January 16, 2017, from <http://www.census.gov/quickfacts/table/PST045216/00>
- Uy, J. P., & Galvan, A. (2017). Acute stress increases risky decisions and dampens prefrontal activation among adolescent boys. *NeuroImage*, 146, 679-689, doi:10.1016/j.neuroimage.2016.08.067.
- Van Doorn, M. D., Branje, S. J. T., & Meeus, W. H. J. (2008). Conflict resolution in parent-adolescent relationships and adolescent delinquency. *The Journal of Early Adolescence*, 28, 503-527, doi:10.1177/0272431608317608.
- Weymouth, B. B., Buehler, C., Zhou, N., & Henson, R. A. (2016). A meta-analysis of parent-adolescent conflict: Disagreement, hostility, and youth maladjustment. *Journal of Family Theory & Review*, 8, 95-112, doi:10.1111/jftr.12126.
- Wichary, S., Mata, R., & Rieskamp, J. (2016). Probabilistic Inferences Under Emotional Stress: How Arousal Affects Decision Processes. *Journal of Behavioral Decision Making*, 29, 525-538, doi:10.1002/bdm.1896.

- Wolff, J. M., & Crockett, L. J. (2011). The Role of Deliberative Decision Making, Parenting, and Friends in Adolescent Risk Behaviors. *Journal of Youth and Adolescence*, 40, 1607-1622, doi:10.1007/s10964-011-9644-8.
- Ziv, Y., Cassidy, J., & Ramos-Marcuse, F. (2002). The conflict task coding system. Unpublished manuscript. University of Maryland, College Park, Maryland

Table 1 *Comparison of Baseline Demographic Characteristics Between Discussion Conditions*

Demographic Characteristic	Control (<i>n</i> = 19)				Conflict (<i>n</i> = 21)				<i>p</i>
	<i>M</i>	<i>SD</i>	#	%	<i>M</i>	<i>SD</i>	#	%	
Age	14.94	1.08			14.95	0.97			<i>p</i> = 0.99
Adolescent Gender (% female)			11	57.9			11	52.4	<i>p</i> = 0.72
Ethnicity									<i>p</i> = 0.16
African American or Black			15	78.9			11	52.4	
Asian American or Asian				NA			1	4.8	
Hispanic or Latino/a (Spanish)			1	5.3				NA	
White, Caucasian American, or European			5	26.3			10	47.6	
Parent Marital Status									<i>p</i> = 0.98
Never married			5	26.3			6	28.6	
Married/living together			11	57.9			12	57.1	
Separated/divorced			3	15.8			3	14.3	
Family Weekly Earnings									
\$500 or less			6	31.6			2	9.5	<i>p</i> = 0.12
\$501 and \$900			5	26.3			11	52.4	
\$901 or more per week			8	42.1			8	38.1	

Table 2 Means (*M*) and Standard Deviations (*SD*) of Psychophysiology, Discussion Task Behavior, Risk-taking Propensity, and Conflict, and Comparison Between Discussion Conditions

Variable	<i>M</i>		<i>SD</i>	<i>t</i> -Test	<i>p</i>
Adolescent Baseline HF-HRV	7.10		1.10	1.73	<i>p</i> = 0.09
Control Condition (<i>n</i> = 19)	7.41		0.95		
Conflict Condition (<i>n</i> = 21)	6.81		1.17		
Adolescent Discussion HF-HRV	7.36		0.93	1.94	<i>p</i> = 0.06
Control Condition (<i>n</i> = 19)	7.65		0.83		
Conflict Condition (<i>n</i> = 21)	7.10		0.95		
Adolescent Hostile Behavior	2.02 (0.50)		1.52 (0.50)	-1.14 (χ = 0.10)	<i>p</i> = 0.26 (0.75)
Control Condition (<i>n</i> = 19)	1.73 (0.47)		1.04 (0.51)		
Conflict Condition (<i>n</i> = 21)	2.28 (0.52)		1.84 (0.51)		
Adolescent Pre-Task BART	36.65		13.07	-0.09	<i>p</i> = 0.92
Control Condition (<i>n</i> = 19)	36.44		13.36		
Conflict Condition (<i>n</i> = 21)	36.84		13.13		
Adolescent Post-Task BART	37.86		13.97	-0.48	<i>p</i> = 0.63
Control Condition (<i>n</i> = 19)	36.74		13.92		
Conflict Condition (<i>n</i> = 21)	38.87		14.27		
Adolescent-Interview of TTI Argue/Fight	6.17		3.64	0.66	<i>p</i> = 0.51
Control Condition (<i>n</i> = 19)	6.58		3.39		
Conflict Condition (<i>n</i> = 21)	5.81		3.90		

Note. Adolescent hostile behavior violated distributional assumptions and was dichotomized into none (0) and any hostile behavior (1) during the discussion task. Descriptive statistics for dichotomous hostile behavior are presented in parentheses. HF-HRV = high frequency band (.12-.40 Hz) of heart rate variability. BART = balloon analogue risk task. TTI = To(may)to-To(mah)to Interview to assess conflict

Table 3 *Correlations amongst Psychophysiology, Discussion Task Behavior, and Risk-taking Propensity, Controlling for Pre-task Risk-taking Propensity*

Variable	Control Condition			Conflict Condition		
	1	2	3	1	2	3
1. Adolescent Discussion HF-HRV	--			--		
2. Adolescent Hostile Behavior	-0.16 (-0.02)	--		0.16 (-0.12)	--	
3. Adolescent Post-Task BART	-0.21	0.05 (-0.09)	--	-0.36	-0.13 (0.18)	--

Note. Correlations for dichotomous hostile behavior are in parentheses. HF-HRV = high frequency band (.12-.40 Hz) of heart rate variability. BART = balloon analogue risk task.

Table 4

Heart Rate Variability as a Mediator between Discussion Condition and Risk-taking Propensity, Moderated by Hostile Behavior (N = 40)

		HF-HRV (M)		Post-task BART Risk-Taking (Y)	
		Coefficient	95% CI	Coefficient	95% CI
Discussion Condition (X)	a ₁ →	-0.56* (0.27)	-1.08, -0.04	c'	0.38 (1.82)
HF-HRV (M)				b ₁	-2.20* (0.96)
Hostile Behavior (W)				b ₂	0.05 (1.90)
HF-HRV x Hostile Behavior (M x W)				b ₃	-4.59* (2.02)
Pre-task BART Risk-Taking (U ₁)	a ₂ →	0.02 (0.01)	-0.00, 0.04	b ₄	1.05** (0.08)
		R ² = 0.19		R ² = 0.86	
		Indirect Effect	95% CI		
No Hostile Behavior		-0.05 (0.64)	-1.61, 1.08		
Hostile Behavior		2.52* (1.41)	0.42, 6.43		

Note. Discussion Condition is coded Control = “0” and Conflict = “1”. Hostile behavior is coded None = “0” and Present = “1”.

* $p < .05$, ** $p < .001$ Regression coefficients are unstandardized; standard errors are in parentheses. HF-HRV and hostile behavior are mean centered. HF-HRV = high frequency band (.12-.40 Hz) of heart rate variability. BART = balloon analogue risk task. CI = confidence interval.

Fig. 1 A) Conceptual model depicting second-stage moderated mediation of the direct effect of discussion condition on risk-taking propensity (c'), and the conditional indirect effect of discussion condition on risk-taking propensity through heart rate variability (HRV)

B) Statistical model illustrating the direct effect of discussion condition on risk-taking propensity (c') was not significant, and the significant conditional indirect effect of discussion condition on risk-taking propensity through HRV was contingent on hostile behavior

Note. $*p < 0.05$ HF-HRV = high frequency band (.12-.40 Hz) of heart rate variability

BART = balloon analogue risk task