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Victimized by Peers and Aggressive: The Moderating Role of Physiological Arousal and Reactivity

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The goal of this study was to examine how individual differences in physiological arousal and reactivity moderated the relation between peer victimization and reactive and proactive aggression. Participants were 58 adolescents (61.2% boys; 54.9% African American) in the age range of 12–15. Participants self-reported peer victimization, reactive aggression, and proactive aggression. Cortisol and respiratory sinus arrhythmia (RSA) were measured from participants before and during an online game in which they were socially rejected by unfamiliar peers. Results indicated that the relation between peer victimization with reactive aggression was significant and positive at low levels of resting RSA and when RSA withdrawal after rejection was high. The association between peer victimization with reactive and proactive aggression was also significant and positive at high levels of anticipatory cortisol. Findings provide further insight into the moderating role that physiological processes may have in understanding individual differences to peer adversity.

Peer victimization, or being the target of aggression by peers, is a pervasive challenge throughout development. In the United States, approximately 60% of adolescents report having been the target of peer victimization at least once (Romano, Bell, & Billette, 2011). Others find that 10%–20%

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of youth report being severely or chronically victimized over time (Perry, Kusel, & Perry, 1988; Solberg & Olweus, 2003). Peer victimization has particularly negative consequences for multiple aspects of adolescents' adjustment, including emotional, behavioral, social, psychological, and academic adjustment (McDougall & Vaillancourt, 2015). Peer victimization often leads to internalizing problems; peer-victimized youth report being more lonely, anxious, and depressed and have lower self-esteem and self-concept compared to non–peer-victimized youth (Hawker & Boulton, 2000).

In addition to internalizing problems, aggressive behavior has been identified as both a consequence and a risk factor for peer victimization (Reijntjes et al., 2011). Some research suggests that victimization and aggression exacerbate each other over time, with victimized youth becoming more aggressive and aggression increasing the risk for later victimization (e.g., Barker et al., 2008; Haltigan & Vaillancourt, 2014; Hanish & Guerra, 2002; Logan-Greene, Nurius, Hooven, & Thompson, 2015). However, other studies have failed to find this relation (e.g., Dhami, Hoglund, Leadbeater, & Boone, 2005) or only small or moderate concurrent associations between victimization and aggression (e.g., Pouwels & Cillessen, 2013; Schwartz, 2000). We suggest that these mixed findings indicate that the relation between victimization and aggression may be moderated by other factors.

One reason for the mixed findings may be because the relation depends on the type of aggressive behavior assessed—that is, whether the aggression is *proactive* or *reactive*. Whereas proactive aggression is goal-oriented and deliberate, reactive aggression is an angry, defensive response to provocation (Crick & Dodge, 1996). A number of studies have found large positive correlations between reactive aggression and peer victimization but not proactive aggression and peer victimization (e.g., Camodeca, Goossens, Terwogt, & Schuengel, 2002; Lamarche et al., 2007; Poulin & Boivin, 2000; Salmivalli & Helteenvuori, 2007). The association between peer victimization and reactive aggression may reflect that youth who are concurrently victimized by their peers and are also aggressive tend to be disruptive and have poor emotion regulation skills (Schwartz, 2000; Toblin, Schwartz, Gorman, & Abou-ezzeddine, 2005). Adolescents who become angry or frustrated in response to negative peer experiences and are unable to effectively regulate their emotions may be at increased risk of responding with aggressive behavior or lose conflicts amidst angry outbursts. Thus, the goal of the present study was to examine how arousal and emotion regulation, as measured by individual differences in physiological arousal prior to a peer-interaction task and after rejection that occurs during the task, may moderate the relation that victimization has with reactive and proactive aggression.

The Stress Response System

Stressors such as peer victimization threaten individuals' physical and psychological well-being. The stress response system's primary function is to restore and maintain homeostasis, or stable internal conditions, through a process called *allostasis* (McEwen, 1998). In addition to the stress responses' role in allostasis, differences in physiological arousal are thought to influence sensitivity to environmental conditions by selectively encoding, attending to, and processing information from the environment (Del Giudice, Ellis, & Shirtcliff, 2011). A highly responsive stress response system can enhance sensitivity (and an unresponsive stress response system can dampen sensitivity) to both positive and negative environmental influences.

Although physiological arousal is an adaptive response to stress, dysregulated arousal, including heightened and blunted arousal, can have negative consequences for short-term and long-term maladjustment, particularly in regard to internalizing and externalizing symptoms (Scarpa & Raine, 1997). The current study examined two components of the stress response system, before and after an online peer-interaction task: (a) respiratory sinus arrhythmia (RSA) as an indicator of parasympathetic nervous system (PNS) functioning, and (b) cortisol as an indicator of the hypothalamic–pituitary–adrenal (HPA) axis.

Parasympathetic nervous system. The PNS is involved in the body's restorative functions. Activation of the PNS results in reduced physiological arousal and enables individuals to calm themselves. Reduced arousal is primarily achieved through the vagus nerve (tenth cranial nerve). The vagus nerve acts as a brake in which inhibition or disinhibition of vagal tone can calm or excite an individual (Porges, 2007). In response to stress, the vagal brake withdraws and allows an individual to attend to and engage with a stressor to facilitate adaptive responses (Porges, 2001).

A commonly used measure of the PNS is RSA, or the high-frequency heart rate variation related to respiration. RSA largely reflects variations in vagal control of the heart and is thus thought to be a relatively pure index of the PNS (Berntson et al., 1994; Bernston, Quigley, & Lozano, 2007). RSA at rest is thought to reflect a capacity for emotion regulation, with higher levels indicating better regulatory abilities (Beauchaine, 2001; Porges, 2007). In line with this conceptualization, high resting RSA has been linked with positive indices of adjustment (Beauchaine, 2001) and prosocial behavior (Cui et al., 2015). Low RSA has also been found to be positively associated with externalizing behavior and aggression (Mezzacappa, Kindlon, & Earls, 1999; Erath, Tu, & El-Sheikh, 2012), especially for boys (Beauchaine, Hong, & Marsh, 2008).

Researchers have also examined decreases in the vagal brake, or RSA withdrawal, in response to stress. RSA withdrawal is an adaptive response that facilitates attention and mobilizes resources necessary to effectively cope with and respond to environmental demands (Porges, 2007). Greater RSA withdrawal in response to a range of stressors has been found to be associated with less dysregulation (Cui et al., 2015; Hessler & Katz, 2007) and with less aggression, misconduct, and fewer externalizing problems (Hinnant & El-Sheikh, 2009; Kibler, Prosser, & Ma, 2004). In addition, low RSA withdrawal has been found to strengthen the relation between internalizing problems and aggressive behavior (Aults, Cooper, Pauletti, Jones, & Perry, 2015; Graziano & Derefinko, 2013). A recent meta-analysis found that greater RSA withdrawal in children was associated with less externalizing, internalizing, and academic problems (Graziano & Derefinko, 2013).

HPA axis. Another component of the stress response system, the HPA axis, has a delayed and longer response to stress compared to the autonomic nervous system, which activates immediately in response to stress (Hostinar & Gunnar, 2013; Sapolsky, Romero, & Munck, 2000). In response to stress, the HPA axis activates a series of cascading events that culminates in the secretion of glucocorticoids, including cortisol. The release of cortisol induces physiological and psychological changes, including increased cardiovascular functioning, reductions in reproductive processes, and increased cognition and awareness, that enable an individual to better cope with a stressor (Sapolsky et al., 2000). The HPA axis has been shown to be particularly sensitive to situations that are unpredictable or uncontrollable and challenges that involve social evaluation or threaten relationships with others (Booth, Granger, & Shirtcliff, 2008; Miller, Chen, & Zhou, 2007).

Associations between cortisol and aggression have been mixed (for a review, see van Goozen, Fairchild, Snoek, & Harold, 2007). Some research has found that blunted levels of cortisol are associated with greater levels of antisocial behavior (e.g., Shirtcliff, Granger, Booth, & Johnson, 2005), relational aggression (Murray-Close, Han, Cicchetti, Crick, & Rogosch, 2008), and aggression in clinically referred boys (e.g., van Goozen, Matthys, Cohen-Kettenis, Buitelaar, & van Engeland, 2000). Regarding reactivity to stressors, there seems to be positive associations between heightened cortisol reactivity and aggression (Rudolph, Troop-Gordon, & Granger, 2010), externalizing problems (Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010), and reactive aggression (Lopez-Duran, Hajal, Olson, Felt, & Vazquez, 2009).

The Moderating Role of Arousal

There is a theoretical basis to assume that individual differences in physiological reactivity to stress may predict differences in how environmental stressors, like peer victimization, are related to behavioral adjustment. The diathesis-stress model (Sameroff, 1983), the biological sensitivity to context (Ellis & Boyce, 2008), and the differential susceptibility hypotheses (Belsky & Pluess, 2009) posit that there are individual differences in vulnerability to adversity. Although these models may differ in how they consider the effects of environmental advantage, they all suggest that individual differences in physiological reactivity to stressful conditions would make individuals more vulnerable to negative environmental conditions like peer victimization.

Research findings have supported these ideas using a variety of physiological and environmental indices. Obradović et al. (2010) found that children in conditions of high adversity, as indexed by parental stress and depression, harsh parenting, marital conflict, and financial stress, had more externalizing problems when they had low RSA reactivity and high cortisol reactivity to social, cognitive, and emotional challenges. Patterns of physiological arousal and reactivity have also been found to moderate the relation between marital conflict and delinquency. For instance, low level of resting RSA and RSA augmentation to stress strengthened the relation between exposure to marital conflict and delinquency (El-Sheikh, Hinnant, & Erath, 2011).

Finally, and most relevant to the current study, Rudolph et al. (2010) examined the moderating role of HPA axis arousal in anticipation of interacting with an unfamiliar peer on the relation between peer victimization and aggression. They found that peer victimization was positively associated with teacher-reported aggression in young adolescents who exhibited high, but not low, cortisol in anticipation of interacting with another peer. These results suggest that when confronted with a possible stressor, such as peer victimization, adolescents with high anticipatory cortisol are more prone to enacting maladaptive behavior strategies, such as reactive aggression, compared to adolescents with low levels of arousal.

Context Specificity

However, there is growing evidence that reactivity and its relation to adjustment may depend on the context or task in which it is assessed (Graziano & Derefinko, 2013; Hastings, Nuselovici, et al., 2008; Hastings, Sullivan, et al., 2008; Lafko, Murray-Close, & Shoulberg, 2015; Murray-Close et al., 2014; Obradović, Bush, & Boyce, 2011).

A meta-analysis found that that the effect sizes of RSA's associations with adjustment indices were smaller when measured in cognitively challenging tasks relative to RSA measured under emotionally challenging tasks (Graziano & Derefinko, 2013). Furthermore, Obradović et al. (2011) found that RSA withdrawal in response to different types of tasks was differentially related to externalizing problems. Children with high RSA withdrawal during a cognitively challenging task had the highest levels of externalizing problems, whereas those who had high RSA withdrawal during an interpersonally stressful task had the lowest levels of externalizing problems. There is also evidence that greater RSA withdrawal during relatively common or benign interpersonal interactions (e.g., meeting and interacting with unfamiliar peers) may indicate adjustment difficulties, including both internalizing and externalizing problems (Hastings, Nuselovici, et al., 2008).

Thus, mounting evidence suggests that adaptive physiological responses may depend on the context in which physiological responses are assessed. Recent studies have assessed physiological reactivity to peer frustration (Rudolph et al., 2010; Rudolph, Troop-Gordon, & Granger, 2011), provocation (Hubbard et al., 2002), ostracism (e.g., Sijtsema, Shoulberg, & Murray-Close, 2011), recollections of peer problems (e.g., Murray-Close et al., 2014; Wagner & Abaied, 2015), social presentation (Trier Social Stress Test; e.g., Bouma, Riese, Ormel, Verhulst, & Oldehinkel, 2009), interactions with unfamiliar peers (Hastings, Nuselovici, et al., 2008), and conversations under peer evaluation (e.g., Erath & Tu, 2014). However, to our knowledge, no other published studies have examined physiological reactivity to online evaluation and rejection by peers, despite the rise in online communication for adolescents (Lenhart, 2015). The current study evaluated physiological responses during an online peer chat-room paradigm. Adolescents completed a profile and viewed the profiles of other (fictitious) peers. Adolescents were asked to vote someone out of the chat room and were subsequently told that they were voted out by the group. The task used in this study may be similar to studies using *Cyberball* (Williams, Cheung, & Choi, 2000), a virtual ball-toss game, because it induces perceptions of rejection by unfamiliar peers. However, the current paradigm may have felt more personal compared to *Cyberball* because participants shared information about themselves and may have felt others had evaluated them negatively. Further, in current study's paradigm, the adolescent was relatively passive in that they were unable to actively cope with or refute the peer rejection/stressor, compared to other tasks like the Trier Social Stress Test or in-person social interactions. Therefore, this paradigm offered a unique context in which to examine physiological reactivity following a personal online social rejection that did not allow the target to actively engage with their rejecters.

The primary goal of the present study was to examine how physiological arousal and reactivity, as indexed by RSA and cortisol, in the context of online peer rejection, would moderate the relation between peer victimization and reactive and proactive aggression. Based on past findings that have demonstrated stronger correlations between reactive aggression and victimization compared to proactive aggression and victimization (e.g., Hubbard et al., 2002), it was hypothesized that peer victimization would be only moderately associated with reactive aggression but unrelated to proactive aggression. Second, regarding physiological arousal, it was hypothesized that victimization would be positively associated with reactive aggression in adolescents with low, but not high, levels of resting RSA. Similarly, it was hypothesized that peer victimization would be associated with reactive aggression at high, but not low, levels of cortisol in anticipation of interacting with unfamiliar peers. In addition, RSA withdrawal was also hypothesized to moderate the relation between peer victimization and reactive aggression such that there would be a positive relation for adolescents who exhibited low RSA withdrawal, but not high RSA withdrawal, in response to social rejection. Lastly, victimization was hypothesized to be positively related to reactive aggression at high levels of cortisol reactivity but not low.

Method

Participants

The sample consisted of 58 adolescents (age range 12–15 years, 62.1% boys, M_{age} = 14.12, *SD* = 1.14) who were recruited for a study about adolescents' social interactions. Thirty participants were recruited from a database of local addresses and corresponding phone numbers for families in the community. A total of 700 letters mailed to local addresses described the study, and participants were subsequently contacted by phone on evenings and weekends. Of the families mailed letters, 443 could not be reached via phone for various reasons (e.g., number disconnected or no answer), 70 people who were contacted did not want to participate, 55 families were interested in participating but could not due to limited availability, and 71 families had no children or had children outside of the age range. A total of 61 families were scheduled to participate, but 31 of these families did not participate because of cancellations, scheduling conflicts, or no-shows. The remaining participants were recruited on a volunteer basis from local church youth groups, the YMCA, and Grades 6–8 of a private middle school.

The final sample was comprised of 45.1% European American and 54.9% African American youth. Approximately 55% of the adolescents' parents/guardians were married, 29.5% were single, 3.2% were separated, 9.7% reported being divorced, and 1.6% reported being divorced and remarried. The majority (59.6%) of the adolescents lived with both their mother and father, while 33.3% reported living with their mother, 1.8% reported living with their father, and 5.3% reported living with a family member other than their mother or father. Approximately half (50.9%) of the parents/guardians reported having at least a college degree, 31.6% reported having some college education, 12.3% had a high school degree, and 5.3% reported having not completed high school.

Procedure

All procedures were approved by the university institutional review board of the first author. Adolescents and one parent/guardian visited the lab after 2 p.m. on a weekday or weekend afternoon in order to control for diurnal changes in cortisol. At the beginning of the visit, adolescents were separated from their parent/guardian for the duration of the lab visit and instructed that they would be playing an online, interactive game with other peers their age after they completed some questionnaires. During the visit, parents completed online questionnaires not used in the present study. After completing the questionnaires, adolescents were connected to physiological equipment by a sex-matched research assistant and given instructions about the game they would be playing. After watching a 5-min relaxing video, adolescents were instructed to drool 1.5 ml of saliva into a cryogenic vial. All saliva samples were stored at −20°C within 30 min of collection until later thawed and analyzed for cortisol. Adolescents then participated in the *Survivor* peer interaction paradigm (described in detail under the Online Peer Interaction section). Additional saliva samples were collected at 5, 20, and 40 min after rejection. After completing *Survivor*, participants were disconnected from the physiological equipment and completed more online questionnaires. At the end of the lab visit, the adolescent and parent were each compensated $30 for their time.

Measures

Peer victimization. Participants completed the Adolescent Peer Relations Instrument (APRI), which assesses experiences with bullying and peer victimization in school (Parada, 2000). Of interest in the current study were items pertaining to peer victimization. The measure includes items that assess verbal victimization (six items; e.g., "I was called names I didn't like"), physical victimization (six items; e.g., "Something was thrown at me to hit me"), and social victimization (six items; e.g., "A student ignored me when they were with their friends"). Adolescents responded to each item on a 5-point Likert scale (1 = *never*, 2 = *sometimes*, 3 = *once or twice a week*, 4 = *several times a week*, and 5 = *everyday*). Subscales of peer victimization were highly correlated with one another (*r*s ranging .61–.67); thus, items were combined to create an overall score for peer victimization by taking the average of the responses to all items (α = .93).

Aggression. Participants completed a 36-item self-report instrument designed to differentiate both the underlying forms and the functional expressions of aggression, including overt and relational forms of reactive and proactive aggression (Little, Jones, Henrich, & Hawley, 2003). Participants rated how true each item was for them on a 4-point scale from *not at all true* to *completely true*. A proactive aggression score was computed by averaging the responses to the items for the overt proactive and relational proactive subscales (12 items; α = .93). Example items include "I often start fights to get what I want" and "To get what I want, I often put others down." A reactive aggression subscale was computed by averaging the items across the overt reactive and relational reactive subscales (12 items; α = .88). Example items include "If others have angered me, I often hit, kick, or punch them" and "When I'm hurt by others, I often get back at them by saying mean things to them."

Online peer-interaction task. At the beginning of the laboratory visit, the adolescents were told that they would be playing an online, interactive game called *Survivor* with other adolescents their age who were also participating in the same study (in reality, the peers did not exist), with the objective of the game to survive each round and become the only remaining player to not be voted out by the other players. This paradigm mimics possible social interaction and social rejection that adolescents may face in their everyday lives at school and online (Asher, Rose, & Gabriel, 2001; Sampasa-Kanyinga & Lewis, 2015) and has been used in numerous studies with children and adolescents (e.g., Reijntjes, Dekovic, Vermande, & Telch, 2008; Reijntjes, Stegge, Terwogt, Kamphuis, & Telch, 2006; Reijntjes et al., 2011; Thomaes et al., 2010).

The adolescents had their photograph taken at the beginning of their visit and were told that it would be uploaded to the game. After completing questionnaires, adolescents were connected to the physiological equipment. Then adolescents were informed on screen that their picture, along with their answers to the personal questions (e.g., "What is your favorite/band singer?' "What do you like to do in your spare time?" and

"What do you like about yourself the most?"), would be transmitted over the Internet and viewed by the other players, who would then make decisions about who they would vote out of the game. Subsequently, a screen with pictures and descriptions of each of the six other players was presented one at a time for careful review. The peers consisted of three boys (two Caucasian and one African American) and three girls (two Caucasian and one African American) in the age range of 12–15 years. Adolescents were reminded that at a later point they would have to vote one of them out of the game.

Participants progressed through the game by examining each of the bogus player profiles. After viewing the last profile, the participant was instructed to decide which of the coplayers she or he wished to vote out of the game. Upon voting, a 60-s on-screen message appeared indicating that the computer was counting the votes of the other players to determine who would be voted out of the game. After the 60-s period, the name of the participant was displayed in flashing red font for 10 s indicating that they were voted out of the game. A message then appeared on the screen informing the participant that feedback was being collected from the other players, but the game shut down after 60 s due to programmed technical difficulties.

Respiratory sinus arrhythmia. Prior to playing *Survivor*, three disposable electrocardiogram (ECG) electrodes with 7% chloride wet gel were placed on the adolescent in a standard lead configuration. ECG and respiratory data were collected according to guidelines provided by MindWare Technologies, Inc. (MindWare, Gahana, OH). The ECG filter was set with a gain of 1,000 Hz with a low cutoff of 0.5 Hz and a high cutoff of 45 Hz. Data were collected at 500 samples per second. A muscle-noise band-pass filter was also used, with a low-pass filter and a high-pass filter of .25 Hz and .40 Hz, respectively. Respiration was measured with a chest-strain gauge that produces voltage when stress is applied via the expansion of the thorax or abdomen and then amplified and filtered with a gain of 1,000 Hz and a low cutoff of 5 Hz.

RSA was calculated by using the spectral analysis method (Berntson et al., 1997) with MindWare Technologies' software (heart rate variability [HRV] Version 3.1.1). This program digitizes the ECG signal and derives an interbeat interval (IBI) by using an algorithm designed to detect the peak of an R-wave; artifacts are flagged by algorithms enabling visual inspection and editing when necessary. The IBI is converted to a time series and linearly detrended before being cosine-tapered and submitted to a fast Fourier transformation (Berntson et al., 1997). RSA is then quantified as the natural log of the integral power within the high-frequency band of respiration (.12–.40 Hz).

Baseline RSA was collected during a 5-min period during which participants were instructed to sit quietly while watching a relaxing video depicting serene images with calming music. The first 2 min were used as an acclimation period, allowing participants to get used to wearing the equipment and relax. RSA during the third and fourth minutes of the baseline period were averaged and used as an indicator of RSA at rest (baseline RSA; across the third and fourth minutes $\alpha = .90$).

RSA withdrawal was calculated by first subtracting RSA collected during the 1-min period following peer rejection from baseline RSA. Thus, higher scores indicate greater RSA withdrawal, and lower scores indicate less RSA withdrawal. This change score was then regressed on baseline RSA. The residualized change scores from the regression were saved and used in analyses involving RSA withdrawal. This approach is recommended because change can be correlated with levels at baseline (Goyal, Shimbo, Mostofsky, & Gerin, 2008).

Anticipatory cortisol and cortisol reactivity. Saliva collection occurred between 2:45 p.m. and 6:00 p.m. The average time of first collection was 4:15 p.m. (SD = 1 hr 20 min). Prior to the assessment, adolescents were instructed to not exercise, eat, or drink for 1 hr before coming into the laboratory. As the adolescents waited to play an online interactive game with their peers, they were instructed to passively collect saliva in their mouth and drool 1.5 ml of saliva into a cryogenic vial. This first sample was designated as anticipatory. Saliva was also collected at 5, 20, and 40 min after rejection. Saliva samples were frozen within 30 min of collection at –20°C until later assayed by the first and fourth authors. Saliva was assayed by using Salimetrics' cortisol assay kit (Salimetrics, State College, PA), in which sensitivity is 0.007–3.0 μg/dl. All samples were assayed in duplicate and retained if the interassay coefficients of variation were less than 15%. The duplicate scores were averaged and used for analyses. Cortisol reactivity was calculated by subtracting anticipatory cortisol from cortisol collected at 20 min after rejection. This change score was then regressed on anticipatory cortisol. The residualized change scores from the regression were saved and used in analyzes involving cortisol reactivity.

Results

Missing Data

Originally, 67 adolescents were recruited and participated in the study. However, the sample was reduced to 58 because five adolescents indicated that they did not believe the peers in the social interaction paradigm were real and four did not complete any of the self-report measures or were missing all the physiological data due to refusal or equipment malfunction. The 58 participants included did not differ on ethnicity ($\chi^2 = 0.84$, $p = .36$) or sex ($\chi^2 = 2.65$, $p = .10$) from those who were excluded.

Of the 58 participants in the sample, three did not have data for peer victimization, two did not report either peer victimization or aggression, nine did not have adequate saliva samples for analysis, and three did not have valid baseline RSA or RSA reactivity data. The *t* tests indicated that adolescents with missing data did not differ from adolescents with complete data on age, $t(56) = 0.35$; reactive aggression, $t(54) = 1.20$; proactive aggression, $t(54) = 0.75$; peer victimization, $t(51) = 0.10$; baseline RSA, $t(53) = 0.04$; RSA reactivity, $t(54) = 1.16$; anticipatory cortisol, $t(54) = 0.32$; or cortisol reactivity, $t(48) = 0.38$ (all *p*s > .15). In addition, chi-square tests indicated no differences between adolescents with and without missing data on sex, $\chi^2(1) = 3.27$, $p = .07$, or ethnicity variables, $\chi^2(1) = 0.19$, $p = .66$. In order to use data from all 58 adolescents and maximize power, full information maximum likelihood estimation was used to handle missing data in M*plus* Version 7 (Muthén & Muthén, 2012). Maximum likelihood handles missing data by estimating the value of an unknown parameter (i.e., missing value) that is the most consistent with other observed variables.

Data Analysis Plan

First, descriptive statistics were computed and correlations among study variables were examined. Then a series of hierarchical regression analyses were run to investigate primary study hypotheses. Peer victimization and the physiological variables were centered prior to analysis. Reactive aggression and proactive aggression were entered as dependent variables. At Step 1, proactive aggression and reactive aggression were entered as control variables when not used as the dependent variable. Age and sex were also entered at Step 1 as control variables. In addition, in analyses involving cortisol, the time of day that the saliva sample was collected was entered as a control. At Step 2, peer victimization and the physiological variable of interest were entered. At Step 3, the Peer Victimization × Physiological variable interaction was entered. Significant interactions were probed at 1 *SD* above and below the mean according to the procedures outlined by Aiken and West (1991). Regions of significance, or the values of the moderator for which the regression of aggression on victimization is statistically significant, were also examined by using Preacher, Curran, and Bauer’s (2006) online utility. Three-way interactions involving sex were explored in preliminary analyses, but no interaction involving sex was significant. Thus, sex interactions are not included in the models presented.

Descriptive Analyses

Descriptive statistics and correlations among the variables were first examined in IBM SPSS (International Business Machines Statistical Package for the Social Sciences) Version 22 (see Table 1). Peer victimization was negatively related to age. Of particular interest, peer victimization was not significantly related to reactive or proactive aggression. Proactive aggression was positively correlated with reactive aggression and anticipatory cortisol. Anticipatory cortisol was negatively associated with the time of day the sample was collected and positively associated with cortisol reactivity. Baseline RSA was positively associated with RSA withdrawal.

Repeated-measures t tests comparing baseline RSA ($M = 7.18$, $SD = 1.13$) and RSA collected after peer rejection ($M = 7.10$, $SD = 1.22$), $t(55) = 0.60$, $p = .55$, indicated that there was no significant difference in RSA across the two periods. However, the repeated-measure t test indicated that anticipatory cortisol ($M = 0.16$, $SD = 0.15$) was significantly higher than cortisol collected after rejection ($M = 0.12$, $SD = .08$), $t(48) = 10.36$, $p < .001$.

Baseline RSA

The hypotheses that baseline RSA would moderate the relation between peer victimization and reactive aggression but not peer victimization and proactive aggression were first tested. As seen in Table 2, age and sex were nonsignificant predictors of reactive aggression, but proactive aggression was a significant predictor. Neither peer victimization nor baseline RSA were significant predictors of reactive aggression, but the Peer Victimization × Baseline RSA interaction was. The interaction was examined at the mean and 1 SD above and below the mean of baseline RSA. As seen in Figure 1a, analysis of simple slopes revealed that peer victimization was positively associated with reactive aggression at low levels of baseline RSA ($b = 0.32$, $p < .01$) but not significantly associated with reactive aggression at mean levels of baseline RSA ($b = 0.13$, $p = .09$) or high levels of baseline RSA ($b = -0.06$, $p = .43$). The region-of-significance analysis for the interaction indicated that victimization was positively related to reactive aggression when baseline RSA was below 7.10 (45.5% of cases).

The moderating effect of baseline RSA on peer victimization predicting proactive aggression was next tested (see Table 2). Age and sex were not significant predictors of proactive aggression, but reactive aggression was.

Table 1. Means, standard deviations, and correlations among variables

Variables	*N*	Mean	*SD*	1	2	3	4	5	6	7	8
1. Age	58	14.16	1.16	—	—	—	—	—	—	—	—
2. Saliva collection time	58	975.9	80.61	.03 (58)	—	—	—	—	—	—	—
3. Peer Victimization	53	1.73	0.93	−.35* (53)	.06 (53)	—	—	—	—	—	—
4. Reactive Aggression	56	1.8	0.59	.16 (56)	−.14 (56)	.06 (53)	—	—	—	—	—
5. Proactive Aggression	56	1.23	0.38	.12 (56)	−.15 (56)	.10 (53)	.58* (56)	—	—	—	—
6. Baseline RSA	56	7.18	1.13	−.20 (55)	.02 (55)	.001 (50)	−.16 (53)	−.02 (53)	—	—	—
7. RSA Withdrawal[a]	55	−0.15	1.02	−.19 (55)	.06 (55)	−.04 (50)	.07 (53)	−.07 (53)	.32* (55)	—	—
8. Anticipatory Cortisol	56	0.16	0.14	.19 (56)	−.30* (56)	−.11 (51)	.21 (54)	.27* (54)	−.16 (53)	.22 (53)	—
9. Cortisol Reactivity[a]	50	−0.04	0.08	−.18 (50)	.20 (52)	−.16 (47)	.19 (50)	.15 (50)	−.11 (50)	−.25 (50)	.93*** (50)

Note. Numbers in parentheses are indicative of the number of participants with complete data for the correlational analysis.

[a]Withdrawal and reactivity are presented in the table as raw change scores, not residualized scores. RSA = respiratory sinus arrhythmia.

*$p < .05$.

**$p < .01$.

Table 2. Regression coefficients associated with reactive and proactive aggression

	Baseline RSA		RSA withdrawal		Anticipatory cortisol		Cortisol reactivity	
	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2
Reactive aggression		0.34***		0.34***		0.35***		0.35***
Step 1								
Age	0.09		0.09		0.09		0.09	
Male	0.13		0.13		0.05		0.05	
Proactive	0.57***		0.57***		0.55***		0.55***	
Sample time	—		—		−0.05		−0.05	
Step 2		0.00		0.06*		0.01		0.01
Victimization	0.05		0.06		0.06		0.05	
Physiology	−0.07		0.23*		0.06		0.09	
Step 3		0.10***		0.05*		0.04*		0.00
Vic × physio	−0.35***		0.27*		0.56*		0.08	
Proactive aggression								
Step 1		0.35***		0.35***		0.35***		0.35***
Age	0.02		0.02		0.02		0.02	

Continued

Table 2. Regression coefficients associated with reactive and proactive aggression (*Continued*)

	Baseline RSA		RSA withdrawal		Anticipatory cortisol		Cortisol reactivity	
	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2
Male	0.15		0.15		0.13		0.13	
Reactive	0.56***		0.56***		0.55***		0.55***	
Sample time	–		–		–0.49		–0.49	
Step 2		0.00		0.03		0.06*		0.06
Victimization	0.11		0.09		0.14		0.07	
Physiology	0.04		–0.13		0.24*		–0.22	
Step 3		0.01		0.01		0.06*		0.01
Vic × physio	0.16		–0.10		0.60*		–0.16	

Note. RSA = respiratory sinus arrhythmia.

*$p < .05$.

**$p < .01$.

***$p < .001$.

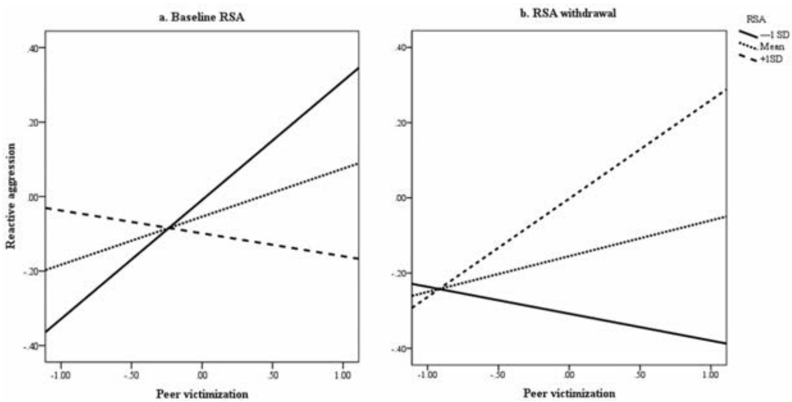

Figure 1. The moderating effect of baseline respiratory sinus arrhythmia (RSA) and RSA withdrawal on peer victimization and reactive aggression.

Neither peer victimization, baseline RSA, nor the Peer Victimization × Baseline RSA interaction were significant predictors of proactive aggression.

RSA Withdrawal

The hypothesis that RSA withdrawal in response to peer rejection would moderate the relation between peer victimization and reactive aggression was next tested. As seen in Table 2, RSA withdrawal was significantly related to reactive aggression, but this was moderated by peer victimization. As seen in Figure 1b, analysis of simple slopes revealed that there was a significant effect between peer victimization and reactive aggression at high levels of RSA withdrawal (b = 0.26, p = .03) but a nonsignificant association at the mean (b = 0.10, p = .20) and at low (b = –0.07, p = .40) levels of RSA withdrawal. The region-of-significance calculation showed that victimization was related to reactive aggression when RSA withdrawal was above 0.35 (23.6% of cases).

Proactive aggression was next tested (see Table 2). Peer victimization, RSA withdrawal, and the Peer Victimization × RSA withdrawal interaction were nonsignificant predictors of proactive aggression.

Anticipatory Cortisol

The hypothesis that anticipatory cortisol levels would moderate the relation between peer victimization and reactive aggression was next tested. As seen in Table 2, there was a significant Peer Victimization × Anticipatory Cortisol interaction. As seen in Figure 2a, analysis of simple slopes revealed

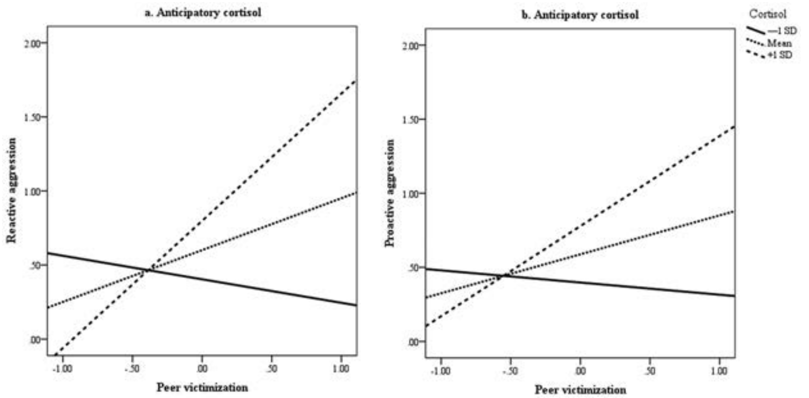

Figure 2. The moderating effect of anticipatory cortisol on victimization and proactive aggression and on peer victimization and reactive aggression.

that peer victimization was negatively associated with reactive aggression for levels of anticipatory cortisol that were −1 *SD* below the mean (b = −3.79, p = .04) but positively associated with reactive aggression at mean levels (b = 0.35, p = .04) and at +1 *SD* above the mean on anticipatory cortisol (b = 4.49, p = .04). The region-of-significance analysis found that victimization was related to reactive aggression when anticipatory cortisol was above 0.16 (33.9% of cases).

Next, the moderating effect of anticipatory cortisol was tested for proactive aggression (see Table 2). Peer victimization was not a significant predictor of proactive aggression but anticipatory cortisol was. The Peer Victimization × Anticipatory Cortisol interaction was also significant. As illustrated in Figure 2b, simple-slope analyses indicated that peer victimization was not significantly associated with proactive aggression at −1 SD level below the mean of anticipatory cortisol (b = –0.08, p = .29) but was significantly positively associated with proactive aggression at the mean (b = 0.26, p = .01) and levels of anticipatory cortisol that were +1 *SD* above the mean (b = 0.61, p = .02). The region-of-significance tests showed victimization was positively related to proactive aggression when anticipatory cortisol was above 0.14 (41.4% of cases).

Cortisol Reactivity

The hypothesis that cortisol reactivity would moderate the relation between peer victimization and reactive aggression was tested (see Table 2). Neither peer victimization, cortisol reactivity, nor the Peer Victimization × Cortisol Reactivity interaction were significant predictors of reactive aggression.

Lastly, the moderating effect of cortisol reactivity on proactive aggression and peer victimization was tested (see Table 2). Neither peer victimization, cortisol reactivity, nor the Peer Victimization × Cortisol Reactivity interaction were significant predictors of proactive aggression.

Discussion

Aggression has been identified as both a cause and a consequence of peer victimization (Reijntjes et al., 2011), but the magnitude of associations between peer victimization and aggression have been variant. Understanding why and under what contexts some victimized adolescents are aggressive may be important for mitigating negative adjustment outcomes. The primary goals of this study were to examine (a) the concurrent relation between peer victimization and aggression and (b) how individual differences in RSA and cortisol prior to an online peer interaction and in response to social rejection moderated the relation of peer victimization with reactive and proactive aggression.

The hypotheses that peer victimization would be moderately associated with reactive aggression but unrelated to proactive aggression were partially supported. In contrast to some past research (e.g., Camodeca et al., 2002), we did not find an association between peer victimization and reactive aggression. However, aggressive victims are less common compared to nonaggressive victims (Schwartz, Proctor, & Chien, 2001), and our sample may have been too small to detect this relation. This finding may also reflect the reality that not all victimized youth are reactively aggressive (Little et al., 2003; Schwartz, 2000). Instead, many victimized adolescents are more withdrawn or submissive (Hawker & Boulton, 2000). Additionally, as our results demonstrate, physiological processes may moderate how environmental experiences, like peer victimization, predict adjustment (Belsky & Pluess, 2009; Ellis & Boyce, 2008).

As hypothesized, peer victimization was associated with greater reactive aggression in adolescents with low levels of baseline RSA but not at mean or high levels. These findings align with the existing literature that has found a negative relation between resting RSA and externalizing problems (Erath et al., 2012; Mezzacappa et al., 1999) and are consistent with research findings that suggest resting RSA is a measure of emotion regulation (Beauchaine, 2001). Low levels of resting RSA may indicate a diminished ability to regulate emotions when confronted with a difficult situation or a conflict with a peer. Thus, when provoked by peers, these youth may be more likely to respond in a dysregulated manner and reactively aggress. Alternatively, it may also be that a child who has trouble regulating his or her emotions and tends to be reactively aggressive may also be an easy target for peer victimization.

An unexpected pattern of results emerged for RSA reactivity in which there was a positive relation between peer victimization and reactive aggression in adolescents with high levels of withdrawal in response to peer rejection. RSA withdrawal has been considered to be adaptive in response to challenges in that removal of the parasympathetic brake should allow the sympathetic nervous system to facilitate fight-or-flight responses. In most past research, RSA withdrawal has been negatively associated with dysregulation and externalizing problems (Cui et al., 2015; Hinnant & El-Sheikh, 2009). However, some suggest that RSA withdrawal may also indicate emotional lability or increased vigilance toward a stressor (Beauchaine, 2001; Sijtsema et al., 2011), especially if the situation is common or benign for most individuals (Hastings et al., 2008).

As noted, reactivity and its relation to adjustment may vary depending on the context in which reactivity is assessed. Many other studies that have examined RSA withdrawal have used a wide range of stressors, including conflict discussions (Shirtcliff et al., 2005), frustration tasks (Hinnant & El-Sheikh, 2009), or competitive tasks between peers (Rudolph et al., 2010). In our study, RSA withdrawal was assessed after a personal social rejection that they could not actively engage with or address. In addition, participants believed that additional feedback from the peers was being collected. Thus, high RSA withdrawal after rejection may indicate that adolescents were more aroused by and paid more attention to the rejection stressor and were anxiously awaiting further feedback. In contrast, adolescents with lower withdrawal during the postrejection period may have disengaged more quickly from the rejection and were in the midst of RSA recovery.

It is interesting to consider the youth who had high RSA withdrawal after the rejection. Sijtsema et al. (2011) found that rejected and rejection-sensitive girls were more likely to be physically aggressive when they had high levels of RSA withdrawal during rejection via *Cyberball*, also a paradigm in which participants cannot actively address the rejection stressor. Similar results have been found with children in which greater RSA withdrawal in response to interacting with unfamiliar peers was associated with greater internalizing and externalizing behaviors (Hastings et al., 2008). Perhaps adolescents who are emotionally responsive to social rejection, or have a harder time recovering from a social rejection, may be more likely to respond with inappropriate behavioral strategies, such as reactive aggression, when they are also victimized.

As Sijtsema et al. (2011) found that rejection expectations moderated how RSA withdrawal predicted aggression, we also suggest that adolescents' social cognitions about peer rejection may have affected their physiological responses to rejection, and that, in turn, may explain why, for adolescents with greater RSA withdrawal, peer victimization was positively associated with reactive aggression. Gunther Moor, Crone, and van der Molen (2010) found that heart rate slowed in response to peer rejection and was slower to return to baseline when the rejection was unexpected compared to when it was expected. Thus, it may be that RSA withdrawal after peer rejection functioned, in part, based on the expectations that the adolescent had about whether they would be rejected. Based on the findings of Gunther Moor et al., it may be that adolescents who had higher RSA withdrawal after rejection by peers were those who had expected to be rejected. Thus, future research would do well to continue to examine how social cognitions or schema, like rejection sensitivity, explain the relation between victimization and aggression and correspond to RSA withdrawal after rejection (Berntson, Sarter, & Cacioppo, 2006).

The hypotheses regarding the moderating role of anticipatory cortisol were also partially supported. Similar to the results found by Rudolph et al. (2010), we found that peer victimization was negatively associated with reactive aggression at low levels of anticipatory cortisol, and peer victimization was positively associated with both reactive aggression and proactive aggression at mean and high levels of anticipatory cortisol. Our findings were in contrast to those of past studies (e.g., Lopez-Duran et al., 2009), which do not find relations between cortisol and proactive aggression. However, generally these findings suggest that an upregulated stress response is sensitive to environmental contexts (Boyce & Ellis, 2005; Del Giudice et al., 2011), and, as a result, adolescents may be sensitive to negative environmental conditions. Under those circumstances, adolescents may be more likely to enact aggressive behavior.

Cortisol reactivity to peer rejection did not moderate the relation between victimization and reactive aggression or victimization and proactive aggression. The absence of a moderating role of cortisol reactivity may be due to the task used. The adolescents were told that they would be playing a game with peers when they first arrived in the lab, although the *Survivor* task was usually played after they had been in the lab for approximately 1 hr. Adolescents likely found the anticipation of interacting with unfamiliar peers to be more stressful than the game itself. A similar pattern of results emerged in a study by Rudolph et al. (2010), who found that levels of cortisol in anticipation of interacting with an unfamiliar peer strengthened the relation between peer victimization and aggression, but cortisol reactivity in response to the task did not. Future research would benefit from alternative methods of measuring cortisol reactions, such as collecting samples at the beginning of the session in order to better assess changes in response to stress.

Furthermore, although this study was not meant to address bullying per se, findings may have relevance to the literature on bully-victims. Children who are both bullied and bully others tend to be higher than non-involved peers on both reactive aggression and proactive aggression (Salmivalli & Nieminen, 2002). Furthermore, bully-victims have more adjustment difficulties and are more emotionally dysregulated than youth who are only victimized, only aggressive, or neither victimized nor aggressive (Schwartz, 2000; Schwartz et al., 2001; Toblin et al., 2005). In line with that literature, our results suggest that bully-victims would have lower levels of baseline/resting RSA and greater RSA withdrawal after an online peer rejection in which they could not actively cope with the rejection. They may also have higher levels of cortisol in anticipation of interacting with unfamiliar peers but may not differ from other youth in their cortisol reactivity to the social rejection. These cortisol findings are similar to findings reported by Kliewer, Dibble, Goodman, and Sullivan (2012), who, using a person-centered approach, did not find differences among aggressive victims and nonaggressive victims in their patterns of cortisol reactivity to a social stressor. However, they did find differences in α-amylase reactivity, suggesting that future work examining how physiological processes may predict relations between aggression (or bullying) and victimization would do well to include salivary α-amylase as an indicator of sympathetic nervous system (SNS) activity.

This study's primary strength was the use of an ecologically valid peer interaction paradigm designed to elicit peer rejection across multiple measures of physiological arousal. In addition, the use of both reactive and proactive aggression afforded greater insight into the aggressive behavior of peer-victimized adolescents. However, the study was not without limitations. First, although, self-perceptions of peer victimization may be particularly useful when predicting adjustment, future research would do well to also include peer reports of aggression and victimization. Youth who are aggressive tend to underestimate rates of victimization compared to peer reports (De Los Reyes & Prinstein, 2004). Therefore, using peer reports and self-reports of behavior may yield a more nuanced picture of the relations between victimization, physiological responding, and forms of aggression.

Second, the findings of the current study may be limited in some ways by the sample. First, the study used a convenience sample, and the families who were willing to participate in the study may have differed from those who were unwilling to participate or did not respond to recruitment materials. In addition, Graziano and Derefinko's (2013) meta-analysis revealed a small effect size between RSA withdrawal and externalizing behavior problems in children. Despite significant interactions emerging in the present study, the small sample size prevented the identification of smaller effects and may have limited the examination of potential three-way interactions involving sex. Subsequent research using larger sample sizes may be needed to determine whether there are sex differences in our findings.

Future research would also benefit from continued exploration of how the components of the stress response system interact in the prediction of social behavior. Physiological systems do not act in isolation, and there is growing evidence that different patterns of physiological reactivity are uniquely associated with adjustment (Del Giudice at el., 2011). For example, Wagner and Abaied (2015) found that, together, different patterns of SNS and PNS activation moderated the relation between relational peer victimization and reactive relational aggression. Further, children with high levels of resting cortisol and high SNS activity had greater internalizing and externalizing problems compared to children with high levels of resting cortisol and lower SNS activity (El-Sheikh, Erath, Buckhalt, Granger, & Mize, 2008). Considering the interaction among the components of the stress response system may shed greater insight into how individual differences in responsivity are related to behavior and adjustment.

In addition, it will be important for future research to consider how the chronicity of peer victimization may alter physiological functioning. Research findings suggest that exposure to chronic life stress leads to upregulation or downregulation of the stress response system, which could affect how physiological processes are related to behavior. Del Giudice, Hinnant, Ellis, and El-Sheikh (2012) found that different patterns of SNS and PNS activity were related to different levels of family stress, suggesting that chronic stress can alter the functioning of the stress response system. Chronic peer victimization may also alter physiological responses to stress (Del Giudice et al., 2011). Longitudinal work that examines how chronic adversity alters stress response functioning will add to our understanding of the interaction between environment and physiological functioning and how it contributes to psychological and behavioral adjustment.

Peer victimization is a particularly stressful experience for youth. This study's results suggest that peer victimization may be particularly difficult to cope with for youth who are easily aroused by social threats. These youth may be more sensitive to adverse peer experiences, placing them at risk for adjustment problems like aggression. Youth who exhibit heightened physiological arousal may be particularly likely to benefit from intervention efforts aimed at improving regulatory abilities, which may, in turn, help their peer relationships.

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