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Being hot-tempered: Autonomic, emotional, and behavioral distinctions between childhood reactive and proactive aggression

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ABSTRACT

Reactive aggression (RA) is an angry response to perceived provocation. Proactive aggression (PA) is a pre-meditated act used to achieve some goal. This study test hypotheses that (1) individuals high in RA and PA will differ in resting levels of autonomic arousal and (2) RA will be related to emotional and behavioral problems, while PA only to behavioral problems.

Parents of 68 children (age 6–13) reported on child symptoms, reactive/proactive aggression, and behavior problems. Resting heart rate (HR), skin conductance (SC), and HR variability (HRV) were measured in 42 of the children. RA was significantly related to decreased HRV and a trend for decreased SC, while PA was significantly related to increased SC and HRV. RA was significantly related to increased internalizing behaviors and attention deficits, while PA was significantly related to increased hyperactivity/impulsivity and delinquent behavior problems.

Findings support a distinction between child reactive (hot-tempered) and proactive (cold-tempered) aggression in autonomic, emotional (i.e., internalizing problems), and behavioral (i.e., attention deficits, hyperactivity/impulsivity, and delinquent behavior) functioning, and are discussed in relation to theories of antisocial behavior.

Based on the distinction between defensive and predatory aggression in the animal literature (e.g., Moyer, 1976), two corresponding dimensions of aggression in children have been identified (Vitiello and Stoff, 1997). Reactive aggression (RA) is a visceral defensive response to perceived threat or provocation within the context of associated intense fear, anger, or frustration (i.e., hot-tempered). Proactive aggression (PA), on the other hand, involves a relatively non-emotional display of aggression used to intimidate others or to obtain a specified goal (i.e., cold-tempered). It is more often pre-meditated and manipulative.

Proactive and reactive aggressive behaviors are often highly correlated in children, and this correlation has been explained in two ways. First, the two functions often co-occur within aggressive individuals; second, questionnaires may confound form with function, such that common properties of physical/overt forms of aggression may be captured rather than the motivational distinctions between reactive and proactive aggression (Card and Little, 2006; Polman et al., 2007). Despite the intercorrelation, several investigators have found the distinction to be reliable and to be related to a variety of social and cognitive variables (Kempes et al., 2005; Merk et al., 2005). For example, using confirmatory factor analysis, Poulin and Boivin (2000) found that a two-factor model of proactive and reactive aggression fit the data better than a one-factor model, and each factor contributed uniquely to predictions of peer reports of the child's aggression. Further, the two-factor model has been found to be consistent across gender and age (Kempes et al., 2006). As such, it may be important to understand the different risks and causal pathways of these two factors, RA and PA. The current study was undertaken to examine the autonomic, emotional, and behavioral distinctions between these two functions of child aggressive behavior.

1. Theoretical models

RA and PA have been explained by two primary theoretical models. Specifically, RA is rooted in the frustration–anger theory of aggression (Dollard et al., 1939; see Vitaro et al., 2006 for review) such that the motive is to react to the anger–frustration stimulus and injure the perpetrator of the real or perceived threat or provocation. Thus, RA is often described as 'hot-tempered,' capturing the essential feature of strong negative emotion. In contrast, PA is considered to be more instrumental or goal-driven in nature. It is often planned or pre-meditated, and is described as 'cold-tempered' due to a general lack of emotional arousal. Rather

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than an act of frustration, therefore, PA is thought to be rooted in social learning (Bandura, 1973) in that aggressive behavior is regulated by learned reinforcement contingencies.

These two general theories have been expanded in recent years, though the general principles remain. For example, Berkowitz (1990, 1993) extended the frustration–anger theory with the Cognitive Neo-Associationistic (CNA) theory (Berkowitz and Harmon-Jones, 2004), suggesting that through a spreading of activation across the associative network (i.e., thoughts, memories, physiological responses, and feelings) of anger, negative affect can automatically elicit an angry and potentially aggressive response. Similarly, the General Aggression Model (GAM; Anderson and Bushman, 2002) proposes that a primary contributor to anger and aggression involves the spreading of activation. However, it distinguishes between automatic and controlled stages of processing, and proposes that perseverating on hostile information (i.e., a controlled process) can increase the intensity of initially automatic reactions of hostility, anger, and aggression. Like the frustration–anger theory, however, CNA theory and GAM both focus on negative affect as an instigator of RA.

The social learning model has been expanded in social cognitive theories. For example, according to social information-processing (SIP) theory (Crick and Dodge, 1994), both RA and PA are related to cognitive processes in social contexts but may be associated with different temporal stages of processing. Specifically, RA is related to early stages of information processing that are associated with attending to and encoding hostile cues in a social situation as well as making hostile attributions of intent. These are considered automatic processes and theoretically may be consistent with the frustration–anger models noted above. Recently, like the notion of automatic and controlled processes noted in GAM, SIP theory has been extended in models that suggest that anger and/or hostile attributions are automatic processes that can only be inhibited if the individual then engages in effortful control (Dodge, 2006; Wilkowski and Robinson, 2008). PA, on the other hand, is associated with biases in later stages of processing, specifically valuing instrumental over social goals and believing that aggression will lead to positive outcomes (Crick and Dodge, 1996). These latter processes are consistent with the social learning model of Bandura (1973) in emphasizing reinforcement learning patterns that lead to greater self-efficacy for aggressive behavior.

2. Emotional and behavioral functioning and reactive/proactive aggression

Consistent with an association found between youth aggression and emotional problems (e.g., depression and anxiety; Zoccolillo, 1992), the frustration–anger model suggests that RA is related to negative affectivity, especially emotions that increase frustration/irritability and perceptions of threat. In support of the notion of increased emotionality in relation to RA, Dodge et al. (1997) found that reactively aggressive children were more likely to display depression than proactively aggressive children. Additionally, Raine et al. (2006) found that adolescents who engaged in RA were more socially anxious. In a recent meta-analysis, Card and Little (2006) concluded that RA, but not PA, was related to internalizing problems and emotional dysregulation. With regard to threat perception, only RA has been associated with perceptual distortion and information-processing abnormalities (i.e., ideas of reference and hostility; Raine et al., 2006), such as making inaccurate hostile attributions of others' behaviors (Crick and Dodge, 1996; Dodge and Coie, 1987; Orobio de Castro et al., 2005). Overall, these findings support the notion that emotional difficulties are associated with reactive but not proactive aggression.

With the exception of SIP theory and encoding, however, the theoretical models do not appear to indicate clear relationships of reactive or proactive aggression with behavior problems, such as attention problems, attention-deficit/hyperactivity disorder (ADHD), or delinquency, and empirical findings in this regard have also been mixed. For example, some studies found that RA was associated with increased problems in attention and impulsivity, whereas PA was not (Atkins and Stoff, 1993; Conner et al., 2003; Dodge et al., 1997; Kempes et al., 2006). Dodge and colleagues (Crick and Dodge, 1996; Dodge and Coie, 1987) also noted that RA was related to biases in early stages of information processing, which involve reduced attention and encoding of relevant situation cues. Others, however, found that both aggressive functions were related to ADHD-type symptoms (see review by Card and Little, 2006; Conner et al., 2004), or that hyperactivity was uniquely related to PA (Raine et al., 2006). Similarly, some researchers found a specific association between delinquent behaviors and PA. For example, Vitaro et al. (1998) found that proactive, but not reactive, aggressive behaviors at age 12 predicted delinquency and disruptive behavior in mid-adolescence; and Raine et al. (2006) characterized proactively aggressive adolescents as psychopathy-prone and seriously violent. However, in their meta-analytic review, Card and Little (2006) found that delinquency was related to both reactive and proactive aggression. Similarly, disruptive behavior disorders (i.e., Oppositional Defiant Disorder, Conduct Disorder, and ADHD) were related to both RA and PA in a study conducted by Conner et al. (2004). According to Brendgen et al. (2001), PA was predictive of later delinquency-related violence when they receive poor parental supervision, whereas RA was predictive of future dating violence in conditions of low maternal warmth and caregiving. As such, while RA is clearly associated with emotional difficulties, it is not clear if reactive and proactive aggression can be distinguished in terms of behavior problems.

3. Autonomic functioning and reactive/proactive aggression

The autonomic nervous system (ANS) has parasympathetic and sympathetic branches to regulate critical life functions and control the "fight or flight" stress reaction (e.g., Porges, 2007). The sympathetic nervous system (SNS) is concerned with preparing the body for fight or flight in situations of threat or danger; it is associated with responses such as increased heart rate (HR), blood pressure, cardiac output, and skin conductance (SC). The parasympathetic nervous system (PNS) is concerned with the conservation of energy and restoration to a calm state; it is associated with vagally mediated responses such as decreased HR and blood pressure, and increased heart rate variability (HRV; defined as the variation in intervals between heart beats that varies as a function of respiration). While the SNS and PNS are often viewed in terms of their functions under conditions of threat, sympathetic and parasympathetic tone in a resting state may reflect individual differences in the capacity to respond adaptively to internal and external demands placed upon the system. That is, resting activity of the SNS may reflect the individual's preparedness for responding to threat, and resting activity of the PNS may reflect the ability to restore the body's functions after a danger has occurred. In this way, the SNS and PNS are often thought to act reciprocally. In Bernston's model of autonomic space (Berntson et al., 1991), however, it is also noted that the SNS and PNS branches do not always conform to the classical reciprocal pattern (i.e., coupled and coactive), suggesting a multidimensional nature of autonomic responding.

In a review of the literature on the psychophysiology of anger and biological findings on crime, Scarpa and Raine (1997, 2000) proposed that autonomic hyper-arousal may underlie RA. The frustration–anger models are consistent with this notion that RA is associated with heightened emotional and physiological arousal, possibly through spreading of activation. Such autonomic hyperarousal is thought to reflect an automatic stress response (i.e., a defensive motivational state) and negative emotionality to which children react with aggressive behavior. In support of hyperarousal in RA, heightened SNS activity has been associated with aggressive behavior, particularly in contexts of anger and perceived provocation (e.g., Lochman et al., 2000; Zillman, 1983). Reduced PNS activity (as indexed by low heart period variability) also has been associated with both internalizing and externalizing problems (Pine et al., 1998). Consistently, Calkins and Dedmon (2000) found that aggressive boys exhibited lower respiratory sinus arrhythmia suppression, another indicator of reduced PNS functioning, as well as more negative affect and emotion regulation difficulties compared to non-aggressive boys.

Conversely, Scarpa and Raine (1997, 2000) suggested that autonomic under-arousal may underlie PA. One reason that under-arousal can increase the likelihood of aggression is that children attempt to compensate for under-arousal by seeking stimulating and risky situations to raise their arousal level to an optimal state (Eysenck, 1997; Quay, 1965; Raine et al., 1997). Another is that under-arousal may be indicative of fearlessness (Raine, 1993, 1997), thus impairing one's ability to learn from punishment, a primary mechanism of socialization (Lykken, 1957, 1995; Raine, 1993; Scarpa and Raine, 1997). In both instances, physiologically under-aroused children seem disinhibited or fearless, and reward/goal achievement takes on more salience (see Scarpa and Raine, 2004 for a review), consistent with social learning theory. These response patterns, often referred to as arousal theory (see van Goozen et al., 2007), are presumed to reflect general low levels of arousal across systems (e.g., both HR and SC would be low). Thus, RA and PA may reflect individual differences (i.e., emotional, behavioral, and physiological), which may potentially be captured in resting states, and subsequently affect the individual's responses to the environment. Indeed, the literature finds that low baseline/resting level of autonomic arousal is generally related to antisocial behavior (for reviews, see Beauchaine, 2001; Ortiz and Raine, 2004; Raine, 1993; Scarpa and Raine, 2004). A prospective study of adolescent boys, for example, found that low resting HR and SC predicted criminal activity in adulthood (Raine et al., 1990).

To our knowledge, however, only two studies of children have taken into account the two functions of aggression (Hubbard et al., 2002; Pitts, 1997) when studying psychophysiological correlates of aggression. In one study of school-aged children, HR reactivity during a provocation was increased in children with RA compared to those with a combination of reactive/proactive aggression (Pitts, 1997). In another study of second graders, no HR differences were found, but RA was positively related to SC reactivity as well as to angry nonverbal behaviors in response to a frustration challenge (Hubbard et al., 2002). While reactivity is a reflection of change in physiological responses to a challenge, baseline arousal during rest is thought to reflect the general background state of the system as described in arousal theory, thus reflecting more tonic individual differences. It is noteworthy that neither of these studies assessed basal levels of arousal, and so it is not clear if baseline individual differences are affecting the results.

In sum, there is currently little empirical research on the autonomic differences between childhood reactive and proactive aggression. We suggest that there are multiple pathways to aggression, one of which may reflect a defensive or angry fight/flight response (i.e., RA), while another may reflect a fearless or callous personality (i.e., PA), and these would be differentially related to autonomic functioning. Based on the frustration–anger and related theoretical models presented above, RA should be associated with higher resting levels of both HR and SC and presumably lower heart rate variability (HRV), whereby SC reflects sympathetic influence on the eccrine system, HRV reflects parasympathetic/vagal influence on the cardiac system, and HR reflects both sympathetic and parasympathetic cardiac influences. Conversely, based on arousal theory and social learning perspectives, PA should be associated with the opposite autonomic pattern (i.e., resting levels of low HR, low SC, and high HRV), reflecting autonomic under-arousal on the eccrine and cardiac systems.

4. Aims and hypotheses

Based on the above review, there may be identifiable emotional, behavioral, and psychophysiological correlates that distinguish reactive and proactive aggression. The objectives of the current study were twofold. First, this study aimed to fill a major gap in the literature by examining differences in autonomic functioning. If arousal theory is supported, RA would be related to increased ANS activity at rest (i.e., high HR, low HRV, and high SC) and PA to decreased ANS activity at rest (i.e., low HR, high HRV, and low SC). Several psychophysiological measures are obtained in order to assess whether the arousal deficits are generally observed, or if specific patterns emerge over different organ systems. Furthermore, we focus on resting levels of ANS activity, consistent with the large literature showing reduced resting HR and SC in antisocial populations. Furthermore, resting states are thought to reflect individual differences in traits that can influence emotional reactivity and regulation in response to the environment. As such, while the frustration–anger theory refers to situations that elicit anger, more recent conceptualizations suggest that any initial differences in negative affect or physiological arousal can activate the system and increase the likelihood of aggression. On the other hand, under-aroused individuals may actually seek stimulation and engage in risky activities, such as aggression.

Second, this study aimed to clarify previous research on the emotional and behavioral correlates of childhood reactive and proactive aggression, using both diagnostic and questionnaire measures of child behavior problems. Specifically, based on the frustration–anger models, it was hypothesized that "hot-tempered" RA would be related to internalizing and externalizing (i.e., ADHD and delinquent) behavior problems. On the other hand, based on social learning theory, it was hypothesized that "cold-tempered" PA would be specific to externalizing problems. Prior work in this area is extended by (1) assessing reactive/proactive aggression as reported by parents, who may be more apt than teachers to understand the child's motivation for aggressing and (2) dividing ADHD-related symptoms into its sub-factors of attention deficits versus hyperactivity–impulsivity, in an attempt to specify which aspects of ADHD may be more relevant.

Related to both objectives, we addressed the intercorrelation often observed between reactive and proactive aggression. We achieved this first by simultaneously entering both aggressive functions into regressions, which allowed us to control for their co-occurrence and observe the unique relationships of each to the outcome measures. Then we repeated analyses while controlling for physical aggression, which allowed us to control for the overt form of aggression that may be common to both functions, thus distinguishing between form and function.

5. Method

5.1. Participants

The full sample included 68 children (62% boys, 38% girls; 87.5% White, 12.5% Black) between the ages of 6 and 13 years (mean = 9.64, *SD* = 2.08) from the local community and the special education department of local schools in Southwest Virginia. Children were included if they were between ages 6 and 13 years and were attending school. They were excluded if they had a history of mental retardation, psychotic disorders, pervasive developmental disorders, or cardiac problems that would interfere with the measurement of HR or HRV (e.g., arrhythmia and asthma). No children were excluded on the basis of gender or race.

Using the Anxiety Disorders Interview Schedule for DSM-IV (American Psychiatric Association, 1994), Child Version, Parent Interview Schedule (ADIS-P), 10 children in the full sample met criteria for a primary or secondary diagnosis of Generalized Anxiety Disorder, 12 for Social Phobia, 12 for Specific Phobia, 3 for Posttraumatic Stress Disorder, 1 for Major Depressive Disorder, 9 for ADHD, and 13 for Oppositional Defiant Disorder. Twenty-four children (35%) had co-morbid diagnoses, 9 children (13%) had one diagnosis, and 35 children (52%) did not meet criteria for any diagnosis. Eight children (12%) were currently being treated with stimulant medication (i.e., amphetamine salts, methylphenidate hydrochloride, and dextroamphetamine sulfate), while 18 (26%) were taking various other medications (i.e., Sertraline, Divalproex Sodium, Risperidone, Fexofenadine Hydrochloride, Loratadine, and Cetirizine Hydrochloride).

Due to equipment malfunction and time needed for repair, psychophysiological data were lost for 26 children. The mean age for the subsample of 42 children (26 boys, 16 girls; 36 White, 6 Black) was 9.83 years (*SD* = 1.85). Of these children, three met criteria for Generalized Anxiety Disorder, five for Social Phobia, five for Specific Phobia, one for Major Depressive Disorder, four for ADHD, and eight for Oppositional Defiant Disorder on the ADIS-P as either a primary or secondary diagnosis. Eleven of these children (26%) had co-morbid disorders, 5 children (12%) had one diagnosis, and 26 children (62%) did not warrant any diagnosis. In addition, 8 (19%) of these children were currently taking a stimulant medication and 9 (21.4%) were being treated with other medications.

Analyses comparing the subsample with the full sample revealed no significant group differences in sex ($Z = -0.31$, $p = .76$, average rank of 32.79 for subsample and 34.33 for full sample), ethnicity ($Z = -0.59$, $p = .55$, average rank of 33.59 for subsample and 31.93 for full sample), or medication status ($Z = -0.75$, $p = .45$, average rank of 30.36 for subsample and 33.62 for full sample). Thus the two samples seem demographically similar statistically, though differences in medication status may or may not affect generalization of the autonomic findings to the entire sample.

5.2. Measures

5.2.1. Anxiety Disorders Interview Schedule for DSM-IV, Child Version, Parent Interview Schedule (ADIS-P; Silverman and Albano, 1996)

The ADIS-P is a structured clinical interview of parents designed to screen for the presence of common psychological disorders in childhood, including anxiety disorder, mood disorder, Oppositional Defiant Disorder (ODD), Conduct Disorder (CD), and ADHD. Both primary and secondary diagnoses were determined in order to characterize the sample (presented above in Section 5.1). For analyses, dimensional measures were obtained by summing the ratings for any internalizing disorder (i.e., mood or anxiety disorders) (*M* = 22.61, *SD* = 24.08, Range = 0–101), as well as separately for inattentive (*M* = 3.08, *SD* = 3.38, Range = 0–9) and hyperactive-impulsive symptoms of ADHD (*M* = 3.84, *SD* = 4.15, Range = 0–12). Twenty-nine interviews were randomly selected to be videotaped and reviewed for purposes of determining inter-rater reliability. ADIS-P total scores for internalizing disorders correlated at .997; while, ADIS-P total scores for externalizing disorders correlated at .990, indicating very strong agreement across raters.

5.2.2. Revised Parent Rating Scale for Reactive and Proactive Aggression (R-PRPA; Brown et al., 1996)

This scale asks parents to rate the frequency of behaviors reflecting proactive (10 items; e.g., takes things from others, has hurt others to win a game) and reactive aggression (6 items; e.g., gets mad when does not get his/her way, blames others) on a scale of 1 (never) to 3 (very often). Items were summed to form continuous measures for each function.

This measure was adapted from the original teacher form of the same scale, where convergent validity was supported (Brown et al., 1996). In a recent study, our lab also supported validity of this measure, showing that parent and teacher reports both possessed high internal consistency, were significantly related across informants, and showed construct validity in relation to aggressive behavior (Ollendick et al., 2009). Coefficient alpha was .79 and .78 for the items in the proactive and reactive scales, respectively. For our study, 84% of the parents who completed the R-PRPA were mothers, and 13% fathers. Scores for RA ranged from 6 to 18 (*M* = 11.03, *SD* = 2.59), and scores for PA ranged from 10 to 21 (*M* = 12.93, *SD* = 2.59).

5.2.3. Child Behavior Checklist (CBCL; Achenbach and Edelblock, 1983)

This is a widely used standardized instrument which asks parents to rate their child's frequency of certain behavioral and emotional difficulties on a scale of 0 (never) to 2 (often). The instrument yields two broad-band factors (i.e., internalizing and externalizing behavior problems) and eight narrow-band factors (i.e., withdrawn behavior, somatic complaints, anxiety/depression, social problems, thought problems, attention problems, delinquent problems, and aggressive problems). The *t*-scores for the internalizing, delinquent, and attention problems factors were used in this study and have a mean of 50 and standard deviation of 10. Scores between 67 and 70 are generally considered to be borderline significant, while those above 70 are clinically significant. The coefficient alpha for the internalizing, delinquent, and attention problem items were .88, .54, and .79, respectively. The reason for the relatively lower internal consistency of the delinquent problems subscale is unknown and warrants further examination in the future. The internalizing scores ranged from 32 to 75 (*M* = 52.34, *SD* = 10.70), the delinquent problems scores ranged from 50 to 72 (*M* = 54.82, *SD* = 6.28), and the attention problems scores ranged from 50 to 79 (*M* = 56.46, *SD* = 8.04). A scale was also created to assess physical aggression, which was used as a control variable in supplemental analyses. The scale included the sum of the raw scores for items # 20 (Destroys his/her own things), # 21 (Destroys things belonging to his/her family or other children), # 37 (Gets in many fights), and # 57 (Physically attacks people) from the aggressive problems factor. Coefficient alpha for this physical aggression score was .76

5.2.4. Psychophysiological measures

HR, HRV, and SC were measured using the VU-AMS ambulatory monitoring system (Vrije Universiteit, Amsterdam) during 4 min of rest, after a 10-min acclimation period. Indices of HR (in beats per minute; bpm) and HRV (Root Mean of the Squared Successive Differences; RMSSD) were derived from the electrocardiogram (ECG), using the VU-AMS. The amplified ECG is passed through a bandpass filter of 17 Hz (high pass) at acquisition and subjected to online automatic trigger level R wave detection. At each R-top, a millisecond counter is read and reset, yielding the raw inter-beat-intervals (IBIs) or R-R wave intervals. As such, HR reflects both sympathetic and parasympathetic control of the heart. IBIs were continuously measured from a 3-lead electrocardiogram attached to the sternum and ribs. Specifically, as instructed in the VU-AMS manual, an active electrode was placed over the jugular notch of the sternum between the collarbones, another active electrode under the left breast 4 cm under the nipple between two ribs, and the ground electrode was placed at the right lateral side of the chest, between the lower two ribs. The average IBI (in milliseconds) were automatically sampled and calculated over 30-s intervals during the 4-min rest period, and then converted to average bpm and to RMSSD by the VU-AMS software (Groot et al., 1998). The average resting HR for the present sample was 86.64 bpm (*SD* = 10.63; Range = 65.44–114.08 bpm). The average resting HRV was 60.48 ms (*SD* = 38.23, Range = 19.25–202.75)

RMSSD provides a sample of the short-term variance of the IBIs and reflects vagal control of the heart as an index of parasympathetic tone. Larger mean successive differences indicate increased HRV. This VU-AMS software does not account for respiration when calculating RMSSD. Although some argue for the necessity of respiratory control in the assessment of HRV (e.g., Grossman et al., 1991; Ritz, 2009), there is also strong support suggesting that respiratory control is unnecessary (e.g., Allen and Chambers, 2007; Denver et al., 2007). Moreover, this measure of HRV has been shown to strongly relate to high frequency power bands in spectral analyses (Friedman et al., 2002), and to cardiac vagal tone as assessed by pharmacological blockade (Hayano et al., 1991), thus providing evidence for its use as an appropriate index of vagal activity.

SC level (measured in microsiemens; μS) was collected through leads on the thenar and hypothenar eminences of the left hand and averaged over 30-s intervals for 4 min of rest. The sampling rate of the VU-AMS for collecting SC data is 2 Hz and a resolution of 0.0125 μS. SC reflects sympathetic functioning and influence on the eccrine glands, although it is cholinergically mediated like the PNS. For this sample, the mean SC level was 3.91 (*SD* = 3.11, Range = 0.33–17.38).

5.3. Procedure

This study was approved by the Psychology Human Subjects Committee and the Institutional Review Board at Virginia Tech, and therefore was performed in accordance with the ethical standards described in the 1964 Declaration of Helsinki. Parents and children were assessed in one session. After obtaining informed consent from parents and assent from children, both completed measures in separate rooms. Parents were interviewed with the ADIS-P and then completed the R-PRPA and CBCL regarding their child's behavior. Because this was part of a larger study, the child also completed other measures at this time that are not reported here.

To allow the children to acclimate to the setting, they were asked to complete some questionnaires and sit calmly for a total of 10 min. Electrodes were placed on the child's left hand and chest as he/she was asked to sit quietly in the chair and relax while resting HR, HRV, and SC were measured. Also, the children were asked not to touch or play with the electrodes. A gentle reminder was provided for any children having problems sitting still. However, none of the children, including those warranting an ADHD and/or Conduct Disorder diagnosis, exhibited notable difficulties during the imposed rest period. Body movement was not controlled for in the assessment of physiological measures, but all artifacts were removed from data analysis while scoring the HRV.

Although not analyzed for this paper, the children then were asked to complete a computerized continuous performance task followed by a computer game against a fictitious opponent and several additional questionnaires. The total session lasted approximately one hour and a half. The parent–child dyads were compensated for their time with a $40 stipend and an entry into a drawing for a $25 gift certificate.

5.4. Data analysis plan

Prior to testing the hypotheses, differences for relevant variables by sex, ethnicity, and age were assessed using *t*-tests and zero-order correlations.

Table 1
Descriptive statistics and *t*-test results for aggression, emotional and behavioral problems, and psychophysiological indices by sex.

	Males *M* (*SD*)	Females *M* (*SD*)	*t*	*p*-Value	Cohen's *d*
R-PRPA Reactive Aggression	10.89 (2.78)	11.30 (2.30)	−0.60	.55	−.15
R-PRPA Proactive Aggression	13.05 (3.11)	13.26 (2.36)	−0.27	.79	−.07
CBCL—Attention Problems	55.29 (7.79)	58.45 (8.66)	−1.42	.16	−.35
CBCL—Internalizing Problems	50.56 (9.82)	53.95 (10.81)	−1.22	.23	−.30
CBCL—Delinquent Problems	53.97 (6.27)	56.64 (6.49)	−1.53	.13	−.38
CBCL—Physical Aggression	.80 (1.51)	.54 (.78)	0.77	.45	.19
ADIS—Attention Deficit	2.84 (4.38)	3.29 (3.39)	−0.48	.63	−.12
ADIS—Hyperactivity/Impulsivity	3.63 (4.29)	4.29 (4.16)	−0.57	.57	.14
ADIS—Internalizing Total	20.92 (24.66)	23.47 (19.08)	−0.43	.67	.11
Heart rate (bpm)	87.55 (11.75)	84.09 (10.10)	0.94	.35	.30
Heart rate variability (RMSSD)	55.58 (27.22)	72.40 (54.02)	−1.27	.21	.40
Skin conductance level (μS)	4.42 (3.67)	3.29 (2.25)	1.06	.29	.34

Note. Total *N* = 68 (df = 66), 42 girls and 26 boys. For psychophysiological measures, *n* = 42 (df = 40), 16 girls and 26 boys. R-PRPA = Revised Parent Rating Scale for Reactive and Proactive Aggression, CBCL = Child Behavior Checklist. ADIS = Anxiety Disorders Interview Schedule for DSM-IV, Child Version, Parent Interview Schedule. Total raw scores were used for PRPA and ADIS measures. *t*-Scores were used for CBCL measure, except physical aggression score.

Intercorrelations between all variables were also examined. Simultaneous regressions were then conducted to evaluate the relationships between RA, PA, and the measures for emotional and behavioral problems and psychophysiological indices. The first set of regressions tested the effect of RA and PA on relevant CBCL scales (Internalizing, Delinquent, and Attention Problems). The second set of regressions tested the effects of RA and PA on Internalizing, Hyperactive/Impulsive, and Inattention scales on the ADIS. The third set of regressions simultaneously tested for the effects of RA and PA on the three psychophysiological measures (HR, HRV, and SC). Supplemental analyses tested for the effects of RA and PA on all the above-noted outcomes, after controlling for the effect of physical aggression as measured by the CBCL. This final analysis was added to control for the confounding role of overt aggression on the effects of reactive and proactive functions. That is, the form of aggression could be driving the results because it cuts across both aggressive functions. Therefore, by controlling for overt physical aggression, the results will show if the effects for RA and PA occur above and beyond the effects for form. For all the regression models, *t*-scores were derived to test for significant effects of each individual variable in the model.

6. Results

6.1. Descriptive statistics

No significant between-group effects were found for sex (see Table 1) or significant associations with age (see Table 2) for any of the emotional and behavioral problems (with the full sample of 68) or psychophysiological indices (with the subsample of 42) with Cohen's *d* effect sizes ranging from small to medium. There was a nonsignificant trend for HRV to decrease with age (r (40) = −.29, p = .08). For most of the comparisons between White and Black participants, variances were unequal across groups likely due to their substantially different proportions; however, despite correcting for unequal variances by computing the F_{max} statistic for each comparison (ratio of largest variance by smallest variance) and confirming that the sampling distribution was not sufficiently distorted ($F_{max} > 3.00$) (Keppel et al., 1992), no significant differences were present. As with prior studies, RA and PA were significantly associated (r (66) = .67, $p < .01$).

We also computed univariate analyses of variance (ANOVA) to explore interaction effects between participant's sex (male or female), ethnicity (White or Black), medication status (no or yes), and age (nine years of age and younger or over age nine) on reactive and proactive aggression for the full sample. No significant interactions emerged, and the interaction effect sizes were small with Cohen's *d* less than .10 in all instances.

A number of significant intercorrelations were found between emotional and behavioral problems for the full sample. Most of the associations among the emotional and behavioral problems were significant and in the positive direction. However, the ADIS Attention Deficit and Hyperactivity/Impulsivity total scores were not associated with the CBCL Internalizing score, and the ADIS Internalizing score was not associated with CBCL's Delinquency scale. There was also a nonsignificant positive trend between ADIS Internalizing score and the CBCL Attention Problems score. Using the subsample, none of the psychophysiological indices were significantly correlated with emotional and behavioral problems, with the exception of a significant positive correlation between HR and RA. Among the physiological measures, resting HR was

Table 2
Intercorrelations between age, emotional and behavioral problems, and psychophysiological indices.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	1.00												
2. R-PRPA Reactive Aggression	.12	1.00											
3. R-PRPA Proactive Aggression	.12	$.67^{**}$	1.00										
4. CBCL—Attention Problems	−.09	$.42^{**}$	$.57^{**}$	1.00									
5. CBCL—Internalizing Problems	.00	$.47^{**}$	$.32^{**}$	$.38^{**}$	1.00								
6. CBCL—Delinquent Problems	.05	$.51^{**}$	$.73^{**}$	$.59^{**}$	$.30^{**}$	1.00							
7. CBCL—Physical Aggression	.02	$.55^{**}$	$.47^{**}$	$.48^{**}$	$.38^{**}$	$.70^{**}$	1.00						
8. ADIS—Attention Deficit	.01	$.54^{**}$	$.73^{**}$	$.69^{**}$	.20	$.54^{**}$	$.44^{**}$	1.00					
9. ADIS—hyperactivity/impulsivity	−.04	$.47^{**}$	$.59^{**}$	$.66^{**}$	.17	$.63^{**}$	$.44^{**}$	$.80^{**}$	1.00				
10. ADIS—Internalizing Total	.10	$.49^{**}$	$.32^{**}$	$.25^{+}$	$.73^{**}$	.18	$.39^{**}$	$.43^{**}$	$.35^{**}$	1.00			
11. Heart rate (bpm)	.04	$.30^{*}$	.22	.20	.24	.18	.06	−.03	.13	.04	1.00		
12. Heart rate variability (RMSSD)	$-.29^{+}$	−.17	.10	.01	−.13	.15	.18	.06	.01	−.05	$-.56^{**}$	1.00	
13. Skin conductance level (μS)	−.15	−.09	.17	.07	.02	.12	.12	.07	.16	.10	$.33^{*}$	−.13	1.00

Note. Total *N* = 68 (df = 66). For analyses with psychophysiological measures, *n* = 42 (df = 40). R-PRPA = Revised Parent Rating Scale for Reactive and Proactive Aggression; CBCL = Child Behavior Checklist; total raw scores were used for PRPA and ADIS measures, *t*-scores used for CBCL measure, except physical aggression score.

* $p < .05$.

** $p < .01$.

\+ $p < .10$.

Table 3
Simultaneous regressions for RA and PA on emotional and behavioral problems and psychophysiological variables.

Dependent variable	Model statistics		Reactive aggression			Proactive aggression		
	F	R (R^2)	β	t	Cohen's d	β	t	Cohen's d
CBCL—Attention Problems	13.89**	.57 (.33)	.07	0.46	.11	.52	3.55**	.87
CBCL—Internalizing Problems	8.20**	.47 (.22)	.48	3.00**	.74	−.01	−0.03	−.01
CBCL—Delinquent Problems	32.63**	.73 (.53)	.03	0.26	.06	.71	5.76**	1.42
ADIS—Attention Deficit	8.08**	.56 (.31)	.40	2.79**	.69	.21	1.42	.35
ADIS—Hyperactivity/Impulsivity	16.20**	.60 (.36)	.14	0.99	.24	.50	3.55**	.87
ADIS—Internalizing Total	9.32**	.49 (.24)	.50	3.29**	.81	−.01	−0.09	−.02
Heart rate (bpm)	1.94	.30 (.09)	.29	1.35	.43	.02	0.08	.03
Heart rate variability (RMSSD)	2.75+	.35 (.12)	−.47	−2.25*	.71	.43	2.05*	.65
Skin conductance level (μS)	2.54+	.34 (.12)	−.41	−1.95+	.62	.46	2.17*	.69

Note. Total N = 68 (df = 66). For analyses with psychophysiological measures, n = 42 (df = 40). bpm = beats per minute. RMSSD = Root Mean Squared Successive Differences. CBCL = Child Behavior Checklist. ADIS = Anxiety Disorders. Interview Schedule for DSM-IV, Child Version, Parent Interview Schedule. beta = Standardized Beta Coefficient. The t-score was derived to test for significant effects of each variable in the regression model presented.
* $p < .05$.
** $p < .01$.
\+ $p < .10$.

inversely related to HRV and positively related to SC, as would be expected.

Additional analyses examined relationships of the physiological indices in the subsample with height, weight, and medication status. No significant relationships were found with height and weight for HR, HRV, or SC. However, there was a nonsignificant trend for an inverse relationship between weight and HRV (r (40) = −.31, p = .06). An ANOVA was conducted to examine any differences in the physiological variables for participants who were receiving stimulants (n = 8), other medications (n = 9), or no medications (n = 25). No significant differences were found between medication groups for HR (stimulants: M = 93.05, SD = 12.26, other medications: M = 84.14, SD = 10.71, none: M = 86.14, SD = 10.01; F (2, 41) = 1.64, p = .21, d = −.48), HRV (stimulants: M = 55.45, SD = 15.96, other medications: M = 72.78, SD = 51.11, none: M = 55.52, SD = 36.02; F (2, 41) = 0.85, p = .44, d = .20), or SC (stimulants: M = 3.94, SD = 2.62, other medications: M = 2.77, SD = 1.69, none: M = 4.43, SD = 3.75; F (2, 41) = 1.12, p = .34, d = .42). However, it should be borne in mind that the sample sizes for medication groups were small.

6.2. Simultaneous regressions

Results of the simultaneous regressions are displayed in Table 3. For the models with emotional and behavioral measures using the full sample, PA was significantly associated with CBCL Attention Problems and Delinquency, as well as ADIS Hyperactivity/Impulsivity; RA was positively associated with CBCL Internalizing Problems, as well as ADIS Internalizing and Attention Deficit scales. These analyses were repeated using only the subsample of participants with complete behavioral and psychophysiological data (n = 42). Results remained unchanged from the findings using the full sample (N = 68). For the models with psychophysiological indices using the subsample, HR was unrelated to RA and PA; however, RA was significantly related to decreased HRV and a nonsignificant trend toward decreased SC, and PA was significantly related to both increased HRV and SC. Effect sizes ranged from small to large with medium and large effects for significant differences.

6.3. Supplemental analyses

Hierarchical regressions were conducted in an effort to separate between form and function by covarying the effect of physical aggression on the relationships between RA, PA, and outcome variables. For these analyses, CBCL physical aggression was controlled in Block 1, while the effects of RA and PA were tested simultaneously in Block 2. Results were similar to the original findings. That is, PA was associated with CBCL Attention Problems (β = .51, t(58) = 2.85, $p < .01$, d = .70) and Delinquency (β = .47, t(58) = 3.29, $p < .01$, d = .81), and ADIS Hyperactivity/Impulsivity (β = .65, t(58) = 3.66, $p < .01$, d = .90). The strength of the association between PA and SC was somewhat weaker after controlling for physical aggression (β = .42, t(41) = 1.90, p = .07, d = .60). RA was associated with increased CBCL Internalizing scores (β = .45, t(58) = 2.76, $p < .01$, d = .67), ADIS Attention Deficit (β = .36, t(58) = 2.34, $p < .05$, d = .58) and Internalizing Totals (β = .49, t(58) = 3.04, $p < .01$, d = .75), as well as decreased HRV (β = −.49, t(41) = −2.25, p = .03, d = .71). The nonsignificant trend for RA and reduced SC also remained, β = −.51, t(41) = −1.79, p = .08, d = −.57. Again, the analyses of the behavioral/emotional indices were repeated with the subsample that had complete behavioral and psychophysiological data, and results were consistent with those of the full sample.

7. Discussion

The primary goal of this study was to test autonomic, emotional, and behavioral distinctions between reactive and proactive functions of aggression in children. According to the frustration–anger theory and prior research, we hypothesized that RA would be associated with general resting autonomic hyper-arousal, emotional difficulties, and behavior problems. In contrast, based on the social learning model and arousal theory, we hypothesized that PA would be associated with general resting autonomic under-arousal and behavioral, but not emotional, problems. These hypotheses were partially supported. Specifically, as hypothesized, RA was related to emotional problems (i.e., internalizing) and attention deficits, while PA was related uniquely to behavior problems (i.e., ADHD-related and delinquent behaviors). The autonomic findings, however, suggested a specific pattern of ANS functioning associated with each aggressive function, rather than general over- or under-arousal. That is, RA was associated with decreased HRV and SC (at the level of a trend), and PA was associated with increased HRV and SC. These autonomic patterns were fairly reliable in that they could not be accounted for by sex, age, height, weight, medication, or form of aggression (i.e., physical aggression). These findings together provide some evidence for a distinction between hot-tempered RA and cold-tempered PA, and suggest that the pathway to each form of aggression may be unique.

7.1. Relationships to emotional and behavioral functioning

Regarding emotional and behavioral distinctions, RA's association with high negative emotionality reflected in mood/anxiety problems, and PA's association with delinquent behavior problems and the hyperactive/impulsive component of ADHD suggests that PA may reflect more chronic and persistent behavioral problems, consistent with findings of Vitaro et al. (1998) and Raine et al. (2006) and inconsistent with the conclusion that delinquency is related to both functions (Card and Little, 2006).

In terms of the behavioral problems, RA and PA were both associated with ADHD-related symptoms. Specifically, PA was associated with Attention Problems on the CBCL. However, when attentional versus impulsive/hyperactive factors of ADHD were separated on the ADIS, RA was uniquely related to the attentional deficits associated with ADHD, and PA was uniquely related to the hyperactive/impulsive symptoms. This suggests that RA and PA are associated with different aspects of ADHD symptomatology and may shed some light on the meta-analytic conclusion that both aggressive functions were related to "ADHD-type" symptoms (Card and Little, 2006). Our results imply that children with RA are impacted by attentional deficits, which may or may not also be related to their emotional difficulties. Children with PA, however, are experiencing the overt behavioral manifestations of motoric over-activity and impulsivity in addition to rule-breaking delinquent behavior.

These findings have theoretical relevance in supporting the frustration–anger models (Dollard et al., 1939; Berkowitz and Harmon-Jones, 2004), which predict heightened negative affect for RA and extends this to anxious and depressed moods. The findings also provide some support for SIP theory, which predicts attentional encoding deficits for RA. However, it appears that the theoretical models for PA in children need to be more fully developed to account for the hyperactive/impulsive component of their antisocial behavior. For example, perhaps hyperactivity/impulsivity interferes with the ability to use more controlled processes to inhibit goal-seeking behaviors or impairs sensitivity to reinforcement contingencies thus leading to reward-dominance.

7.2. Relationships to autonomic functioning

Regarding physiological distinctions, we hypothesized that, if RA and PA were related to general levels of arousal across different organ systems, then they should be associated with either increases or decreases, respectively, in *both* resting HR and SC. Also, we expected decreases or increases, respectively, in HRV (which would be consistent with the HR response). Rather than general associations with ANS over- or under-arousal, however, our findings suggested that RA and PA were associated with different patterns of autonomic functioning. First, neither function was associated with HR. Further, RA was associated with reductions in both parasympathetic influences on the heart (i.e., decreased HRV) as well as sympathetic activity on the eccrine glands (i.e., decreased SC), whereas PA was associated with the opposite pattern (i.e., increased HRV and increased SC). Therefore, we did not see the expected patterns in either HR or SC, although the HRV findings were in the expected direction (i.e., decreased for RA and increased for PA). This pattern of autonomic activity goes beyond predictions made by general arousal theory that heightened sympathetic activity will necessarily be associated with reduced parasympathetic activity. Therefore, these results need to be replicated in future research, and explanations of autonomic distinctions between RA and PA need to delve deeper into the physiological and psychological mechanisms that may be differentially associated with each of the measures (here, HRV and SC).

Considering that low resting HR is one of the most highly replicated psychophysiological findings in relation to childhood aggression (see Ortiz and Raine, 2004 for a review), it is curious that we did not find any significant relationship between HR and reactive or proactive aggression. On the other hand, there are some studies that have failed to replicate this finding (e.g., Calkins and Dedmon, 2000; Garralda et al., 1991; Pine et al., 1998; van Hulle et al., 2000; Zahn and Kruesi, 1993). For example, van Hulle et al. (2000) did not find any significant associations between resting HR and externalizing, delinquent, and aggressive problems. We did find, however, that PA was associated with increased HRV, and RA with decreased HRV. This suggests that in relation to these aggressive functions, vagal contributions to HR modulation may play a stronger role than is reflected by the HR measure alone. That is, HRV may be a more sensitive measure of vagal influence than HR. On the other hand, heightened SC in relation to PA and reduced SC in relation to RA suggest sympathetic involvement as well, at least as it relates to its influence on eccrine glands. Perhaps both HRV and SC tap a common construct that was not measured in this study. Both indices are cholinergically mediated, for example, which could explain a common underlying physiological mechanism.

Behaviorally, however, situations involving PA may require activation of the entire ANS, such that the individual must be prepared to respond to danger but must also maintain a calm state in order to intimidate or obtain a goal. For situations involving RA, reduced HRV may reflect heightened negative emotionality; however, it is less clear why sympathetic SC activity would be reduced or de-activated. It is possible that this finding relates back to a neurobiological model of RA presented by van Goozen et al. (2007), where it was implied that sympathetic under-activity may ironically increase sensitivity to stressors.

This discrepancy may also be explained by Bernston's model of autonomic space (Berntson et al., 1991), which incorporates instances in which the sympathetic and parasympathetic branches of the ANS do not conform to the classical reciprocal pattern (i.e., coupled and coactive), suggesting a multidimensional nature of autonomic responding. Also, Ellis and Boyce (2008) suggest that there is a curvilinear relationship between early psychosocial support versus stress with level of biological reactivity. Specifically, both supportive, low-stress environments as well as stressful, tumultuous environments can promote biological sensitivity to context (BSC) exhibited in the form of high autonomic reactivity. However, the supportive environment seems to serve as a buffer, whereas the stressful environment serves as a risk factor for highly reactive individuals. Individuals from moderately stressful environments are suggested to exhibit low autonomic reactivity. As such, reciprocal inhibition of the PNS and SNS may not always occur, dependent upon the environmental context. Therefore, it is possible that the discrepant autonomic findings between RA and PA in the current study reflect differences in BSC.

As an alternative interpretation, it has been suggested that HR and SC activity partly reflect frontal lobe functioning (Raine, 1993; Raine and Lencz, 1993; Raine et al., 2000, 1991; Tranel, 2000; Sollers et al., 2000; Zahn et al., 1999). In these studies, reduced frontal activity has been related to high HR, low HRV, and low SC, and vice versa for increased frontal activity. Ellis and Boyce (2008) also noted that, higher autonomic reactivity has been associated with better executive functioning as well as the ability to delay gratification when pursuing a goal. This explanation would be consistent with findings that frontal deficits in terms of reduced executive functioning were predictive of self-reported RA in 10- to 12-year-old boys (Giancola et al., 1996). Relatedly, in a brain-imaging study of adult violent offenders, Raine et al. (1998) found that affective (i.e., reactive) murderers demonstrated significantly decreased prefrontal glucose metabolism relative to predatory (i.e., proactive) murderers. Theoretically, therefore, the findings of the current study could reflect reduced frontal lobe involvement in situations of RA, while PA may require the increased control and ability to delay gratification afforded by more frontal activity. Moreover, the notion of frontal lobe dysfunction in relation to RA would suggest that frontal modulation of negative affect and attention is compromised, and this is consistent with our finding of relationships between emotional difficulties and attention-deficit symptoms primarily for RA.

Our findings relative to HRV are also indicative of differences in emotional control or regulation, if HRV is viewed as an indirect measure of vagal tone. Increased vagal tone, as measured through various methods (e.g., RMSSD, spectral analysis, and respiratory sinus arrhythmia), has been associated with appropriate engagement, emotion regulation, and social competence across the lifespan; whereas decreased vagal tone has been associated with both internalizing and externalizing psychopathology (see Beauchaine, 2001 for a review as well as an integration of the polyvagal model with motivational explanations of aggressive behavior). As such, Beauchaine suggested that low vagal tone may reflect a dysregulated affective style and emotional inflexibility that is shared among certain disorders such as depression, panic anxiety, and aggression/hostility. In relation to the current findings, RA would be associated with such compromised emotion regulation/control (reflected in low HRV/vagal tone) and thus leads to behavioral outbursts. On the other hand, PA may be associated with emotion regulation/control that is increased (reflected in high HRV/vagal tone). While increased emotional control is typically considered adaptive, it is being used for antisocial gain in this case, and therefore has negative social connotations.

7.3. Limitations

The findings in this study are encouraging, but they must be interpreted in light of several limitations. First, the sample size was too small and unequal to test for interaction effects, especially for sex (predominantly boys in our sample) or racial status (predominantly White in our sample). Although no systematic sex or racial differences were found, replication on larger samples is necessary, and caution must be taken in generalizing these findings to girls or minority populations. Secondly, the analyses were correlational, making conclusions about causal relationships impossible. Another limitation involves the concern regarding the potential influence of respiration on HRV indices, since respiration was not measured or controlled for in the analyses. On the other hand, some researchers argue that respiratory control is not necessary for HRV assessment (Allen and Chambers, 2007; Denver et al., 2007). Moreover, HRV was measured during rest, in which respiration is not expected to vary significantly, thus reflecting vagal modulation accurately when it is not corrected for respiration (Allen and Chambers, 2007; Houtveen et al., 2002). Lastly, only resting ANS responses, and not reactivity to a provocation, were obtained for purposes of this paper. It is possible that the physiological findings may have been stronger for reactivity scores. However, it is also possible that the rest period could have been perceived as a mild stressor for the children due to anticipatory anxiety.

8. Conclusions

In sum, these findings suggest the importance of distinguishing between reactive and proactive aggression when examining antisocial behavior in children. The findings of this study suggest that RA can be distinguished from PA along emotional, attentional, and autonomic indices. Though speculative, it may be possible that problems with emotion regulation and stress reactivity may be related to deficits in frontal lobe functioning, as reflected in decreased SC and HRV. Such individual differences in frontal functioning can then interact with situational cues by influencing one's actions in response to specific situations. Thus, individuals with a tendency to respond to stress with an angry or defensive response, for example, may be more likely to use RA when faced with provocation or frustration. Conversely, PA may be characterized by increased vagal or parasympathetic control of the heart (reflected in increased HRV) and heightened SC level, which may reflect increased frontal lobe activity and subsequent emotional control. Nonetheless, PA is associated with hyperactivity/impulsivity, which may interfere with effortful control of aggressive impulses or learning from punishment. Thus, individuals with a tendency to value instrumental over social goals, but with low effortful control, may be more likely to use PA when presented with the possibility of instrumental gain. A focus on using aggression for instrumental gain may also reflect a risk for chronic and persistent behavioral difficulties. Such distinctions may not only allow for a more detailed understanding of the mechanisms of aggressive behavior, but may lead to more effective interventions specifically targeting deficiencies associated with each function of aggression.

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