Resting Heart Rate, Guilt, and Sympathy:

A Developmental Psychophysiological Study of Physical Aggression

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This research was supported by a grant from the Canadian Institutes of Health Research. The authors thank the children and caregivers who participated, and the members of the Laboratory for Social-Emotional Development and Intervention who helped with data collection, coding, and processing. Tyler Colasante and Tina Malti declare no conflict(s) of interest.

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Abstract

Although low resting heart rate has been linked to frequent aggressive conduct in childhood, little is known about the interaction of this biological risk with social emotions that protect against aggression across development. With a sample of 5-, 8-, and 12-year-olds (N = 110), we tested whether the negative link between resting heart rate and physical aggression was offset by high guilt and sympathy. Caregivers reported their children's physical aggression and sympathy. Children's electrocardiogram data were collected while they viewed a nondescript video, after which they reported their guilt—or lack thereof—in response to vignettes depicting social transgressions. Lower resting heart rate was significantly associated with higher physical aggression in 5-year-olds who reported low—but not medium and high—levels of guilt, and in 8-year-olds with low—but not medium and high—ratings of sympathy. Neither guilt nor sympathy moderated the resting HR–physical aggression link in 12-year-olds. We discuss how social emotions may help children with low resting heart rates navigate social conflicts and avoid aggressive physical confrontations.

Keywords: physical aggression, resting heart rate, guilt, sympathy, childhood

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Aggressive behavior, defined as that which intentionally causes physical harm, psychological harm, and/or distress to others (Krahé, 2013), has been identified as a core factor in the maladaptive health outcomes of children (Eisner & Malti, 2015). Aggressors and their victims are more susceptible—concurrently and sometimes prospectively—to academic impairment (Brennan, Shaw, Dishion, & Wilson, 2012), peer rejection (Ladd, Ettekal, Kochenderfer-Ladd, Rudolph, & Andrews, 2014), and mental illness (Hodgins, Cree, Alderton, & Mak, 2008; Moffitt, 2003). At the societal level, a lifetime case of untreated aggression costs taxpayers an estimated $2.6 to $4.4 million (Cohen & Piquero, 2009).

Low resting heart rate (HR) is the best-replicated biological risk factor for childhood aggression (Lorber, 2004; Ortiz & Raine, 2004; Portnoy & Farrington, 2015) and among the main physiological risk factors for conduct disorder recognized by the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM-5*; American Psychiatric Association, 2013). Most psychophysiological research has focused on the direct relation of resting HR to aggression (Portnoy & Farrington, 2015). Similarly, an abundance of developmental research has investigated the independent relations of social emotions and aggression. Evidence suggests that guilt and sympathy, for example, highlight the negative consequences of aggression (e.g., the physical pain of victims) and protect against its development from an early age (Lovett & Sheffield, 2007; Malti & Krettenauer, 2013; van Noorden, Haselager, Cillessen, & Bukowski, 2015).

However, the extent to which resting HR and social emotions jointly relate to aggression at different periods of development has not been investigated. Guilt and sympathy have distinct cognitive components—in addition to their affective (i.e., feeling) components—and often require a higher degree of cognitive infusion than basic emotions (Gummerum, Cribbett, Nogueira Nicolau, & Uren, 2013; Malti, 2016). These cognitive components are likely to manifest in the presence and *absence* of a strong physiological response, and may thus play an important role in mitigating aggressive behavior in children with low resting HRs. Such joint associations between biology, emotions, and behavior may contribute to theorizing behind the resting HR–aggression link (Damasio, Everitt, & Bishop, 1996; Raine, 2013) and the identification of protective factors that can be targeted by child-level interventions to offset biological risks for aggression.

Resting HR and Physical Aggression

In the present study, we focused on physical aggression (e.g., attacking others and causing bodily harm) for the following reasons: a) it is thought to be particularly contingent on developmentally invariant factors, such as resting HR, whereas other aggressive and rule-breaking behaviors are more susceptible to contextual factors (e.g., peer pressure-induced exclusive behavior; Eisner & Malti, 2015), b) its consequences are relatively severe and visible to children, thus increasing its likelihood of triggering guilt and sympathetic concern (Zuffianò, Colasante, Buchmann, & Malti, 2017), and c) it occurs—albeit to different extents—in early, middle, and late childhood (Tremblay, 2000, 2010), thus spanning the age groups under study.

Evidence for the heritability of aggression has prompted interest in the biological processes that may serve as reliable correlates of such conduct and/or play a role in perpetuating it from an early age (Raine, 2013). Low resting HR (i.e., in the absence of obvious, arousing external stimuli) has emerged as a consistent autonomic correlate. For example, Ortiz and Raine (2004) conducted a meta-analysis of 45 independent effect sizes and found evidence for significantly lower resting HRs in children and adolescents (ages 3–18, *M*age = 10.8) with high levels of aggression compared to normal and psychiatric controls (*d* = - .44). This finding held regardless of gender, age, method of recording HR, recruitment source of the sample, and study design. With a similar meta-analysis of 46 independent effect sizes disaggregated by type of antisocial behavior, Lorber (2004) found significant effects for studies investigating children's (ages 1–11), adolescents' (ages 12–17), and adults' (age 18 or older) aggression (*d* = -.38) and conduct problems (*d* = -.33), but not psychopathy. Again, no significant moderators were identified. Lastly, Portnoy and Farrington (2015) conducted an updated systematic review and meta-analysis of the low resting HR–aggression relation from childhood to adulthood (ages 1–51, *M*age = 15.9; 115 independent effect sizes). Their findings largely mirrored those of previous meta-analyses, as low resting HR coincided with a 22% increase in aggression on average (*d* = -.20; regardless of demographic and methodological moderators). Collectively, these findings attest to low resting HR as a replicable biological correlate of aggressive conduct.

A number of theories have been put forth to explain the resting HR–aggression link. According to stimulation seeking theory, individuals with low resting HRs are often in an underaroused, unpleasant state and engage in aggressive conduct as a means to relieve their discomfort (Raine, 2013; Sijtsema et al., 2010). The fearlessness hypothesis, on the other hand, suggests that those with low resting HRs show more aggression because they lack the arousal to fear its negative consequences (which impedes the effectiveness of socialization processes, such as punishment, across childhood; Raine, 2013). Along the latter lines, the somatic marker hypothesis may also speak to observed links between resting HR and aggressive behavior. In general, this hypothesis argues that bodily sensations or feelings are linked to their corresponding object or event in the brain and tagged as "somatic markers". To aid decision making in future instances involving similar objects or events, these somatic markers—and associated bodily sensations—are reactivated by the ventromedial frontal cortices (Bartol & Linquist, 2015; Damasio et al., 1996). Children with low resting HRs, then, may lack the physiological responsiveness to consistently generate somatic markers around aggressive physical confrontations that would otherwise guide their decision making in future confrontations away from aggressive outcomes (for a similar explanation, see Peskin et al., 2012).

Consistent nonrelations between age and effect size in resting HR–aggression studies (Lorber, 2004; Ortiz & Raine, 2004; Portnoy & Farrington, 2015) suggest that resting HR is a relatively stable correlate of concurrent aggressive behavior across development. In addition, Ortiz and Raine (2004) found that resting HR predicted subsequent aggression with just as much strength as concurrent studies, despite a median follow-up of 9 years for prospective studies. Raine, Venables, and Mednick (1997), for example, reported that having a lower resting HR as early as 3 years of age predicted higher aggression 8 years later on the cusp of adolescence. These findings warrant the identification of early moderators that mitigate the significant concurrent and prospective predictive power of resting HR on aggression.

Guilt, Sympathy, and the Resting HR–Physical Aggression Link

Despite the evidence in support of resting HR as a relatively static biological correlate of aggression, researchers have been hesitant to apply this status (Raine, 2013) and the *DSM-5* stresses that low resting HR alone is not diagnostic of conduct disorder (American Psychiatric Association, 2013). This stance aligns with growing evidence for biology x environment interactions predicting aggressive conduct (Moffitt et al., 2008; Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010; Raine, 2002). Under this biosocial line of research, the moderators of physiology have been largely social/demographic factors outside the realm of psychological development (e.g., neighborhood-, peer-, and family-level processes that buffer/exacerbate the resting HR–aggression link; Farrington, 1997; Raine, 2002; Scarpa, Tanaka, & Haden, 2008). Promising psychological moderators, such as guilt and sympathy, have been overlooked, despite their well-documented aggression-reducing properties (Lovett & Sheffield, 2007; Malti & Krettenauer, 2013; van Noorden et al., 2015) that can be directly targeted by child-level interventions (Malti, Chaparro, Zuffianò, & Colasante, 2016).

Guilt is commonly referred to as regret over wrongdoing (Kochanska, Gross, Lin, & Nichols, 2002; Malti & Latzko, 2012). Feelings of guilt imply that an individual accepts or anticipates responsibility for causing or associating themselves with a transgression of internalized norms (Hoffman, 2000). To assess guilt feelings in an experimental setting, developmental psychologists typically ask children to imagine themselves committing hypothetical social transgressions and report their corresponding emotions and justifications (Malti, Gummerum, Keller, & Buchmann, 2009; Malti & Ongley, 2014). A meta-analytic review of 42 studies found a significant, negative association between such reports of guilt and aggressive behavioral outcomes in 4- to 20-year-olds (majority ages 7–10; d = .39; Malti & Krettenauer, 2013). These findings support the view that guilt highlights the internal—and sometimes external—negative consequences of aggressive acts, potentially minimizing the likelihood of their occurrence and/or recurrence (Malti, 2016).

Sympathy is a feeling of concern for another that often, but not always, stems from a shared experience of their distress or emotional state. It is frequently confused with empathy, which always involves sharing another's emotional state, but does not always result in concern for that other (Eisenberg, 2000). We focused on sympathy in the present analysis because it necessitates other-oriented concern, which likely motivates children to reconcile and later avoid aggressive acts against others. In their review of 62 studies spanning 3- to 18-year-olds, van Noorden and colleagues (2015) found that bullying was negatively associated with empathy-related responding (including sympathy; overall associations ranged from r = -.15 to r = -.62 and β = -.14 to β = -.44). Children who attend to others in distress and feel concern for them may be more sensitive to victims of aggressive acts and, as a result, less likely to engage in such behavior (Eisenberg, 2000).

As prototypical, complex social emotions, guilt and sympathy have marked cognitive components (relative to basic emotions, such as anger and fear; Gummerum et al., 2013; Malti, 2016). Guilt, for example, involves a causal understanding of the consequences of an act for others and an appreciation that one can act as an agent of harm or good (Malti, 2016), whereas sympathy involves an astute awareness of others and an understanding that their perspectives can differ from one's own (Eisenberg, 2000). If children with low resting HRs are able to express—particularly cognitively—guilt over harming others and/or sympathetic concern in lieu of a strong physiological response, they may be better equipped to navigate social conflicts and avoid aggressive outcomes.

To the best of our knowledge, no cross-sectional/longitudinal studies have examined the susceptibility of the resting HR–aggression link to moderation by psychological factors between age groups/across development. Given more frequent and situationally variable physical aggression in early versus later childhood (Eisner & Malti, 2015; Tremblay, 2000, 2010), the resting HR–physical aggression link may be more malleable in younger children. Alternatively, the effects of resting HR may be more susceptible to moderation by guilt and sympathy in older children if temperamental variables give way to increasing social-emotional factors (and therefore have a lesser impact on social behavior over time; Bates, 2012). For empirical support of this theorizing, see Colasante, Zuffianò, Bae, and Malti (2014).

The Present Study

We tested guilt and sympathy as potential moderators of the resting HR–physical aggression relation in a sample of 5-, 8-, and 12-year-olds. Mediation analyses have been used to help explain the link between resting HR and aggressive behavior (e.g., through increased sensation seeking in adolescence; Sijtsema et al., 2010), and suggest that such children's aggressive proclivities may be channeled into more acceptable outcomes (e.g., high intensity sports, activities, and/or professions; Raine, 2013). However, from the perspective of the current study, moderation analyses are more suitable for identifying social emotions that potentially offset the well-established resting HR–aggression link. Similarly, others have argued that biological and psychosocial factors act independently and interactively to predispose individuals to aggression (Raine, 2002; Wilson & Scarpa, 2014). Thus, rather than arguing that lower resting HR contributes to lower social emotions and thereby higher aggression (as tested by mediation), we argue that aggressive risks in the autonomic domain (i.e., related to low resting HR) depend on development in the social-emotional domain (i.e., levels of guilt and sympathy; a matter of moderation). This position acknowledges that having a low resting HR does not necessarily preclude a child from having high guilt and/or sympathy.

We hypothesized that children with lower resting HRs would be rated higher in physical aggression, but not if they reported high levels of guilt and/or were rated as highly sympathetic. In other words, we expected the protective properties of guilt (Malti & Krettenauer, 2013) and/or sympathy (Lovett & Sheffield, 2007; van Noorden et al., 2015) to offset the aggressive risks of low autonomic arousal (Lorber, 2004; Ortiz & Raine, 2004; Portnoy & Farrington, 2015). We also tested for age differences in these potential moderating effects. However, our corresponding hypotheses remained open based on a lack of related developmental studies and conflicting theoretical viewpoints on the interrelations of these constructs across development. Finally, we controlled for gender and caregiver's highest level of education (as a proxy of socioeconomic status), as studies have linked them to aggressive outcomes in childhood (for gender, see Nivette, Eisner, Malti, & Ribeaud, 2014; for socioeconomic status, see Ludwig, Duncan, & Hirschfield, 2001).

Method

Participants

A sample of 33 5-year-olds (*M*age = 5.23, *SD* = .52, 16 girls [49%]), 36 8-year-olds (*M*age = 8.02, *SD* = .29, 14 girls [39%]), and 41 12-year-olds (*M*age = 12.08, *SD* = .29, 21 girls [51%]) from a major Canadian city participated with their primary caregivers (*N* = 110, 51 girls [46%]). They were recruited from local community centers, events, and summer camps. All children and caregivers were fluent in English.

Caregivers reported their highest level of education with the following breakdown: 4% high school, 22% vocational, 53% bachelor's, and 21% master's/doctoral level. They also reported their ethnicity as follows: 36% Western European, 14% South Asian, 10% East Asian, 8% Eastern European, 5% Caribbean, 4% Southeast Asian, 3% Latin, Central, and South American, 1% West and Central Asian, 1% African, and 18% other/multiple origins. Overall, these distributions were representative of the region from which the sample was drawn (Statistics Canada, 2013).

Procedure

The researchers' institution granted ethical approval. Children and caregivers attended the laboratory for a 30- to 45-minute session. Oral assent was obtained from children and written informed consent was obtained from caregivers. Assessments were conducted with children in a designated room while their caregivers remained in a waiting area and completed a questionnaire. After the assessments, caregivers were debriefed while children were awarded a certificate of completion and an age-appropriate book. All assessments were recorded (video and audio) for data analytic purposes.

Measures

Physical aggression. Caregivers completed five items depicting physical aggression from the narrow-band Aggressive Behavior syndrome scales of the Child Behavior Checklists (CBCL/1.5–5 and CBCL/6–18; Achenbach & Rescorla, 2000, 2001; e.g., "Physically attacks people.") Items were assessed on a 6-point scale (1 = *not at all* to 6 = *very much*; α = .78).

Resting HR. Three-lead electrocardiogram data were recorded from children at a sampling rate of 2 kHz using a Biopac MP150 data acquisition system and a BioNomadix module (Biopac Systems, Goleta, CA, USA). Children were instructed to sit still while they viewed a 120-second video depicting aquatic scenery. Monitoring electrodes were secured slightly below the right clavicle and below the ribs on both sides. Leads from each electrode were connected to a module fastened around the midsection that communicated wirelessly via the MP150 with a computer in an adjacent room running AcqKnowledge 4.2 data acquisition software (Biopac Systems, Goleta, CA, USA). Data were imported to Mindware HRV 3.0.9 (Mindware Technologies, Gahanna, OH, USA) for visual inspection, cleaning, and HR calculation. They were cleaned in 10-second intervals to facilitate ease of processing. If more than 20% of an interval required editing, it was excluded from further analysis (overall rejection rate = 4.6% [i.e., 61/1,320 intervals]).

Guilt. Children were presented six vignettes from the Social-Emotional Responding Task (SERT; Malti et al., 2009), which have been extensively validated by studies on children's social-emotional development (Malti & Ongley, 2014). Two vignettes depicted transgressions in each of the following three domains: antisocial behavior, social exclusion, and prosocial omission. They were accompanied by illustrations matched to the gender of the participating child. Three questions followed each vignette: Question 1 asked, "How would you feel if you had done what [hypothetical victimizer's name] did?" If children said, "I don't know," they were asked, "If you had [behavior of hypothetical victimizer], would you feel good, bad, or good and bad?" Question 2 asked, "Why would you feel [anticipated emotion from Question 1]?" Children's answers were recorded verbatim. Question 3 asked, "How strongly would you feel [anticipated emotion from Question 1]?" Children answered by pointing to a 3-point scale depicting squares of increasing size. Prior to this, 5-year-olds were calibrated with a similar scale depicting animals of increasing size (i.e., a mouse, horse, and elephant corresponding to low, medium, and high intensity emotions, respectively) to ensure they understood the scale format. Two independent raters coded a random subsample (n = 21) of anticipated emotions and reasons from all vignettes. Cohen's κs were .99 and .86, respectively. Disagreements were discussed until a consensus was reached.

Coding. Anticipated emotions following Question 1 were coded as 1 (guilt related) or 0 (not guilt related). Specifically, guilty, bad, sad, and other relevant negatively valenced emotions (e.g., embarrassed/ashamed) were coded as 1, whereas neutral, happy, proud, good, and other (i.e., nonaffectively relevant) responses were coded as 0. Including basic emotional and related correlates of guilt (e.g., simplified reports of negative feelings, such as bad and sad) allowed us to examine guilt-related emotions in children who did not explicitly verbalize guilt, but provided relevant affective responses with consonant reasons (Colasante, Zuffianò, & Malti, 2016; Malti & Ongley, 2014; Tracy, Robins, & Lagattuta, 2005). Justifications following Question 2 were coded as 1 (moral; i.e., references to violating principles of fairness, justice, and/or harm, or to the welfare of others), 2 (sanction based; i.e., references to external sanctions from authority figures, such as teachers and parents, or peers), 3 (hedonistic/justifying; i.e., references to self-centered benefits/excuses for why it was acceptable to transgress), or 4 (other). Only responses coded as 1 (guilt related) for Question 1 and 1 (moral) for Question 2 were deemed indicative of guilt.[1] Corresponding intensity scores of guilt responses were used to add further gradation (1 = *not strong* to 3 = *very strong*). Scores of 0 were retained for responses that were not guilt (guilt-related emotions with 4 [other] reasons, which occurred 8% of the time on average, were coded as missing rather than 0 [not guilt] because it was impossible to ascertain whether their unelaborated justifications reflected moral guilt or not). Resulting continuous scores were aggregated across vignettes and indicated level of guilt after transgressing ($\alpha = .67$).

Sympathy. Caregivers completed a well-validated, five-item scale adapted from Eisenberg and colleagues (1996; e.g., "My child feels sorry for other children who are being teased.") Items were assessed on a 6-point scale (1 = *not at all* to 6 = *very much*; $\alpha = .86$).

Results

Preliminary Analyses

Means and standard deviations of focal study variables for each age group are reported in Table 1. The age groups significantly differed in terms of resting HR, $F(2, 107) = 16.86$, $p <$

[1] It has been theorized that moral—relative to nonmoral—guilt is more likely to be intrinsically motivated, stable, and linked to dispositional aggression (Colasante et al., 2016; Malti, 2016).

.001, $\eta_p^2 = .24$, and guilt, $F(2, 107) = 4.75$, $p = .01$, $\eta_p^2 = .08$. Bonferroni-corrected post hoc comparisons revealed that 12-year-olds had a lower average resting HR than 5- and 8-year-olds, *p*s < .01, 95% CIs [-20.46, -8.27] and [-14.36, -2.46], respectively. Eight-year-olds had a lower average resting HR than 5-year-olds, although this difference was marginally significant, $p = .07$, 95% CI [-12.23, 0.32]. Lastly, 12-year-olds reported higher levels of guilt than 5-year-olds, $p < .01$, 95% CI [0.12, 0.99]. [INSERT TABLE 1 ABOUT HERE]

These significant age group differences were largely reflected in the zero-order correlations reported in the lower half of Table 2 (i.e., based on exact age, older children had lower resting HRs and reported higher levels of guilt than younger children). A marginally significant, negative correlation was also detected between age and physical aggression, such that older children tended to be rated lower in physical aggression. As reported in the upper half of Table 2, we ran partial correlations to investigate our core study variables' interrelations beyond their relations with age. Higher ratings of physical aggression were associated with lower levels of guilt and sympathy when considering variance unique from age. The relationship between resting HR and physical aggression (independent of age) was in the expected (i.e., negative) direction, but not significant. [INSERT TABLE 2 ABOUT HERE]

Hierarchical Multiple Regressions Predicting Physical Aggression

To investigate guilt and sympathy as potential moderators of the resting HR–physical aggression link and developmental differences thereof, we ran a series of hierarchical multiple regressions predicting physical aggression in 5-, 8-, and 12-year-olds, respectively.[2] At step 1 of each regression, we entered gender and caregiver education as control variables. At step 2, we entered resting HR, guilt, and sympathy as core study variables. At step 3, we entered the

[2] To avoid multicollinearity and related interpretational issues stemming, in part, from significant associations between age and our other predictor variables, we ran separate regressions for each age group (rather than testing three-way interactions in an omnibus regression). In doing so, we maintained the ability to investigate our hypotheses regarding developmental differences in the moderating effects of guilt and/or sympathy on the resting HR–physical aggression link.

interactions of Resting HR x Guilt and Resting HR x Sympathy. To ease interpretability and maintain parsimony, we dropped nonsignificant control variables and interactions (Cohen, Cohen, West, & Aiken, 2003; the final, reduced regression models are reported in Table 3).

For 5-year-olds, none of the control variables significantly predicted physical aggression at step 1. At step 2, guilt (albeit marginally) and sympathy emerged as significant, negative predictors of physical aggression, accounting for 6% and 19% of its variance, respectively. Although the main effect of resting HR was not significant at this step, there was a significant interaction of Resting HR x Guilt at step 3, which added a further 11% of explained variance. As depicted in Figure 1, lower resting HR was significantly related to higher ratings of physical aggression for those with low (i.e., -1 *SD*), $\beta = -.53$, $p = .02$, 95% CI [-.97, -.09], but not medium, $\beta = -.15$, $p = .35$, 95% CI [-.47, .17], and high (i.e., +1 *SD*), $\beta = .24$, $p = .36$, 95% CI [-.28, .75], levels of guilt. The interaction of Resting HR x Sympathy was not significant. In the final model, the increases in variance explained by the main effects and the interaction effect were significant, $F(3, 29) = 3.04$, $p < .05$, and $F(1, 28) = 4.79$, $p < .05$, respectively. [INSERT FIGURE 1 ABOUT HERE]

For 8-year-olds, none of the control variables were significant at step 1. At step 2, higher sympathy was significantly associated with lower physical aggression (R^2 = 17%; resting HR and guilt were not). At step 3, the interaction of Resting HR x Guilt was not significant, although the interaction of Resting HR x Sympathy was and accounted for a further 8% of the variance in physical aggression. Lower resting HR was significantly related to higher ratings of physical aggression for those with low (i.e., -1 *SD*), $\beta = -.53$, $p = .01$, 95% CI [-.97, -.10], but not medium, $\beta = -.23$, $p = .10$, 95% CI [-.51, .05], and high (i.e., +1 *SD*), $\beta = .07$, 95% CI [-.32, .46], $p = .73$, ratings of sympathy (Figure 2). In the final model, the increases in variance explained by the main effects and the interaction effect were significant, $F(3, 31) = 5.77$, $p < .01$, and $F(1, 30) = 4.07$, $p = .05$, respectively. [INSERT FIGURE 2 ABOUT HERE]

For 12-year-olds, step 1 control variables were not significantly related to physical aggression. However, gender became a significant predictor with the addition of core study variables at step 2, as girls were rated higher in physical aggression (R^2 = 6%). Sympathy also emerged as a significant, negative predictor at this step (R^2 = 41%). Resting HR and guilt were not significantly related to physical aggression. At step 3, neither of the focal interactions were significant. In the final model, the increase in variance explained by gender and the main effects was significant, $F(3, 37) = 9.78$, $p < .001$. [INSERT TABLE 3 ABOUT HERE]

Discussion

Children with low resting HRs have a heightened risk of engaging in aggressive behavior (Lorber, 2004; Ortiz & Raine, 2004; Portnoy & Farrington, 2015) with serious negative consequences for themselves and their targets (Brennan et al., 2012; Hodgins et al., 2008; Ladd et al., 2014). A focus on social-emotional development may help identify protective psychological moderators of this biological risk—ones that can be targeted by child-level interventions. To address this possibility, we tested the social emotions of guilt and sympathy as potential moderators of the resting HR–physical aggression link in 5-, 8-, and 12-year-olds.

Depending on the age group under consideration, we found evidence for our hypothesized moderation effects, such that high levels of guilt and sympathy offset the negative association between resting HR and physical aggression. To date, biosocial approaches have identified interactions between resting HR and social/demographic variables outside the realm of psychological development (e.g., relationship with parent[s], home background/socioeconomic status, community violence exposure; Farrington, 1997; Raine, 2002; Scarpa et al., 2008).

Building on this list of social aggravating/mitigating factors, the current findings highlight the importance of considering the *social-emotional* strengths of children with low resting HRs (particularly their guilt and sympathy, which are among the most empirically validated protective social emotions; Malti & Krettenauer, 2013; Lovett & Sheffield, 2007; van Noorden et al., 2015).

But how might guilt and sympathy help children with low resting HRs avoid aggressive outcomes in the face of biological risk? The fearlessness hypothesis argues that such children lack fear of sanctions (e.g., punishment) for aggressive behavior (Raine, 2013). Fear of sanctions has been regarded as an important building block of guilt, especially in early childhood (Dys & Malti, 2016; Kochanska et al., 2002). However, it has also been argued that guilt can stem from violating (or the anticipation of violating) internalized moral principles of fairness, justice, and/or harm (Hoffman, 2000; Malti, 2016). If a blunted fear response impedes the effects of sanctions for children with low resting HRs (see Raine, 2013), moral guilt is likely to be a more effective deterrent of their aggression than sanction-based guilt. Indeed, we separated moral and sanction-based guilt responses in our coding procedure and found that high levels of the former buffered the resting HR–physical aggression link.

The somatic marker hypothesis (Damasio et al., 1996) suggests that children with low resting HRs lack the physiological responsiveness to generate somatic markers (i.e., neural tags linking bodily sensations to salient objects/events) for aggressive acts that would otherwise guide their decision making in future aggressive confrontations (Peskin et al., 2012). This interpretation is supported by neuropsychological studies (Blair, Budhani, Colledge, & Scott, 2005; Marsh et al., 2008) in which children with callous-unemotional traits (i.e., low levels of guilt, empathy, and general affective arousal; Frick & Moffitt, 2010) and disruptive behavior disorders show deficits in amygdala functioning (a crucial trigger structure for the initial marrying of a stimulus or event to a somatic state; Bechara & Damasio, 2005; Bechara, Damasio, & Damasio, 2003). While it is generally agreed upon that somatic markers contribute to decision making, there is still considerable debate about how necessary they are for such processes (Linquist & Bartol, 2013). Cognitive factors also play a substantial role in decision making and social emotions require children to employ significant cognitive resources (Gummerum et al., 2013; Malti, 2016). In lieu of a strong physiological response or somatic marker, cognitive anticipation, evaluation, and/or reflection may represent important pathways to guilt and sympathy for children with low resting HRs. Guilt, for example, can arise from evaluating an aggressive act as incongruent with one's moral standards (Malti, 2016)—a scenario that requires neither empathy nor fear (both of which children with low resting HRs tend to lack; Raine, 2013; Zahn-Waxler, Cole, Welsh, & Fox, 1995). Similarly, understanding others' perspectives may promote sympathetic concern for victims of physical harm when an empathic physiological response is lacking (Eisenberg, 2000). In line with these explanations, Ball, Smetana, and Sturge-Apple (2016) found that empathy (an affective capacity) was positively related to moral judgments in a sample of preschoolers, but only for those with low theory of mind (a cognitive capacity; higher theory of mind was associated with higher moral judgments regardless of empathy). Hence, advanced cognitive capacities may provide a sufficient basis for moral functioning in children who lack affective capacities.

Factors that offset low resting HR-related risks in childhood are likely to inform early interventions with lasting effects (given the evidence for long-term prospective links between resting HR and aggression; Ortiz & Raine, 2004). While the measurement of resting HR is considered an informative, reliable, and cost-effective approach to risk assessment (Aldao & De

Los Reyes, 2015), our findings suggest that its clinical utility for childhood psychopathology may be further improved if considered in conjunction with strategies that target children's social-emotional development. Practitioners could facilitate guilt and sympathy in children with low resting HRs by helping them recognize their victims' distress, take responsibility for such distress, and understand how their aggressive behavior violates principles against physical harm. This may result in such children weighing the potential benefits of aggressive acts against their budding internalized moral standards and concerns for the welfare of others (Colasante et al., 2016).

When moderation was present, we found that the physical aggression ratings of children with high resting HRs were less dependent on their guilt and sympathy levels. Another central aspect of the somatic marker hypothesis is that markers themselves are either positively or negatively valenced, and their reactivation provides information about whether an associated object or event was "good" or "bad" on previous occasions (Bartol & Linquist, 2015). Thus, among children who can reliably generate strong somatic markers, somatic cues of foreseen negative repercussions may not necessarily revolve around guilt and sympathy. Given the serious consequences of physical aggression (relative to other aggressive subtypes; Eisner & Malti, 2015), somatic cues for physical aggression based on punishment or popularity may be just as powerful as those aligning with painful feelings of guilt and sympathetic concern. It may also be that somatic cues for children with high resting HRs represent a constellation of deterrents beyond guilt and sympathetic concern.

Children who lacked guilt and/or sympathy *and* had relatively low resting HRs were rated highest in physical aggression. This combined risk aligns with the inclusion of callous-unemotional traits as a specifier for the diagnosis of conduct disorder in the *DSM-5* (American

Psychiatric Association, 2013; Frick & Moffitt, 2010). The callous-unemotional specifier designates a severe subgroup of children with conduct disorder who tend to lack guilt, empathy, and overall affect. While the combination of these deficits may be particularly problematic, the current moderation findings suggest that efficiencies in one of these domains (e.g., social-emotional functioning) may compensate for deficiencies in another (e.g., basal arousal). Future studies should assess the extent to which such findings extend to clinical samples.

We also found developmental differences in the moderating effects of guilt and sympathy on the resting HR–physical aggression link. Guilt was a significant moderator for 5-year-olds, whereas sympathy was a significant moderator for 8-year-olds. Our measure of sympathy tapped into a dispositional tendency for other-oriented concern (Eisenberg et al., 1996). Similarly, high levels of physical aggression at the age of 8 may reflect a dispositional tendency for such behavior (in light of general developmental declines in physical aggression from early childhood onward; Eisner & Malti, 2015). Some children who show high levels of physical aggression by middle childhood tend to exhibit high and stable levels into adolescence and adulthood (Moffitt, 2003). In early childhood, physical aggression tends to be more situationally variable (Eisner & Malti, 2015; Tremblay, 2000, 2010), much like our measure of guilt in everyday social conflict situations (Malti et al., 2009). Overall, this dispositional versus situational alignment of study variables may have partly contributed to the developmental differences in question. Although neither guilt nor sympathy moderated the resting HR–physical aggression link in 12-year-olds, results stemming from stimulation seeking theory may offer an explanation for this nonfinding. Given that stimulation seeking peaks in adolescence (Steinberg et al., 2008), a recent longitudinal study tested an age-effect hypothesis and found that high sensation seeking mediated the relationship between resting HR and antisocial behavior in adolescence, but not preadolescence (i.e., at ages 13.5 and 16, but not at age 11; Sijtsema et al., 2010). Thus, factors other than guilt and sympathy (e.g., sensation seeking) may play a moderating role by 12 years of age.

Limitations of the present study and future directions should also be considered. First, more studies of this type are needed. While we do believe that our findings uphold the possibility that guilt and sympathy disrupt the aggressive consequences of low resting HR, future studies should attempt to replicate them with larger samples across different developmental periods and related psychological variables that may also serve as moderators (e.g., anger, executive functioning, inhibitory/effortful control; Cui et al., 2015; Rothbart & Bates, 2006; Zelazo & Carlson, 2012). Second, we assessed physical aggression only, whereas studies have revealed differential relations between physiology and other subtypes of aggressive behavior (e.g., reactive versus proactive aggression; Raine, Fung, Portnoy, Choy, & Spring, 2014; Xu, Raine, Yu, & Krieg, 2014). Raine and colleagues (2014) found that resting HR was negatively associated with proactive aggression after controlling for reactive aggression, but not vice versa. In addition, Arsenio, Adams, and Gold (2009) found that guilt-related responses were negatively related to proactive—but not reactive—aggression in a sample of low-socioeconomic status adolescents. Thus, testing resting HR, guilt, and sympathy against reactive and proactive aggressive outcomes is a promising future avenue. Finally, issues related to shared-method variance cannot be ruled out (i.e., although guilt was child reported in response to common transgressions, sympathy and physical aggression were caregiver reported via questionnaire, which may have contributed to more consistent and robust effects of sympathy in our regression analyses). Future studies should attempt to replicate our moderation findings with an even more comprehensive multi-informant, multi-method approach.

To conclude, this developmental psychophysiological study was the first to unpack guilt and sympathy as potential social-emotional moderators of the resting HR–physical aggression link. Our findings suggest that some children who develop guilt and sympathy in the face of biological risk may be better equipped to navigate social conflicts and avoid aggressive physical confrontations.

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Table 1

Descriptive Statistics by Age Group

Variables	5-year-olds	8-year-olds	12-year-olds
	M (*SD*; Range)	*M* (*SD*; Range)	*M* (*SD*; Range)
Physical aggression	1.77 (0.92; 1–4)	1.45 (0.55; 1–4.20)	1.48 (0.59; 1–3)
Resting HR	94.21 (11.24; 71.62–115.81)	88.26 (10.46; 63.63–113.37)	79.85 (10.49; 62.28–100)
Guilt	1.30 (0.82; 0–3)	1.58 (0.83; 0–3)	1.85 (0.67; 0.33–3)
Sympathy	4.88 (0.93; 2.4–6)	4.95 (0.83; 3–6)	5.04 (0.83; 1.6–6)

Note. Physical aggression (caregiver reported; scale = 1–6). Resting HR (heart rate in beats per minute). Guilt (child reported; scale = 0–3). Sympathy (caregiver reported; scale = 1–6). *n* = 33, 36, and 41 for 5-, 8-, and 12-year-olds, respectively.

Table 2

Zero-Order and Partial Correlations

Variables	1	2	3	4	5	6	7
1. Physical aggression	—	-.12	-.23*	-.46***	—	.04	-.04
2. Resting HR	-.03	—	-.05	-.11	—	-.11	.07
3. Guilt	-.26**	-.18†	—	.16†	—	.05	-.11
4. Sympathy	-.47***	-.14	.18†	—	—	-.19*	.01
5. Age	-.16†	-.48***	.28**	.08	—	—	—
6. Gender	.04	-.07	.04	-.19*	-.05	—	.03
7. Caregiver education	-.03	.06	-.10	.01	-.01	.03	—

Note. Lower half = zero-order correlations. Upper half = partial correlations controlling for age (exact years up to test date). HR (heart rate). Gender (girls = -.05, boys = .05). Caregiver education (highest level achieved; elementary = 1, graduate = 5). $^{***}p < .001$. $^{**}p < .01$. $^{*}p \leq .05$. $^{\dagger}p < .10$.

Table 3

Multiple Regression Models Predicting Physical Aggression in 5-, 8-, and 12-year-olds

Variables	5-year-olds		8-year-olds		12-year-olds	
	β	95% CI	β	95% CI	β	95% CI
Gender	—	—	—	—	-.27*	-.54, .00
Caregiver education	—	—	—	—	—	—
Resting HR	-.15	-.47, .17	-.23†	-.51, .05	-.16	-.43, .11
Guilt	-.40*	-.75, -.05	-.15	-.47, .18	-.01	-.28, .27
Sympathy	-.35*	-.68, -.02	-.49**	-.81, -.16	-.73***	-1.01, -.45
Resting HR x Guilt	.38*	.03, .74	—	—	—	—
Resting HR x Sympathy	—	—	.28*	.00, .60	—	—
R^2	.35*		.44***		.44***	

Note. β (standardized regression coefficient). R^2 (variance explained). CI (confidence interval). Gender (girls = -.05, boys = .05). Caregiver education (highest level achieved; elementary = 1, graduate = 5). Nonsignificant control variables and interactions were dropped. $^{***}p \leq .001$. $^{**}p < .01$. $^{*}p \leq .05$. $^{\dagger}p \leq .10$.

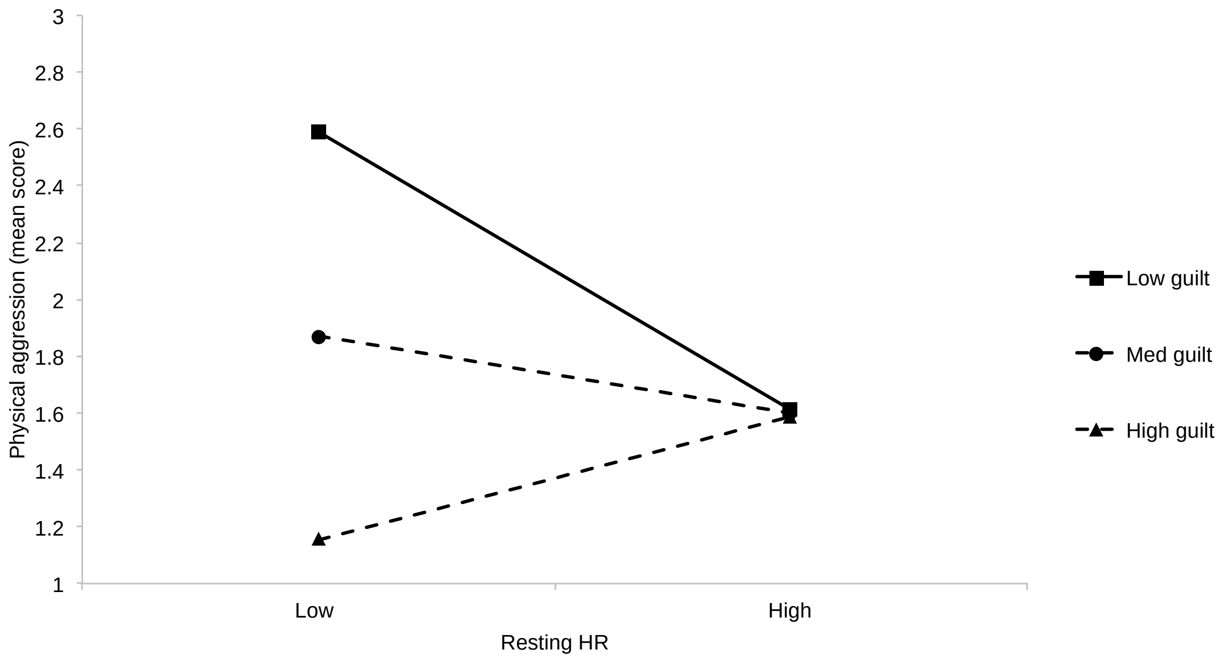

Figure 1. Resting HR in relation to physical aggression for 5-year-olds with low (-1 *SD*), medium, and high (+1 *SD*) levels of guilt. Dotted lines represent nonsignificant effects.

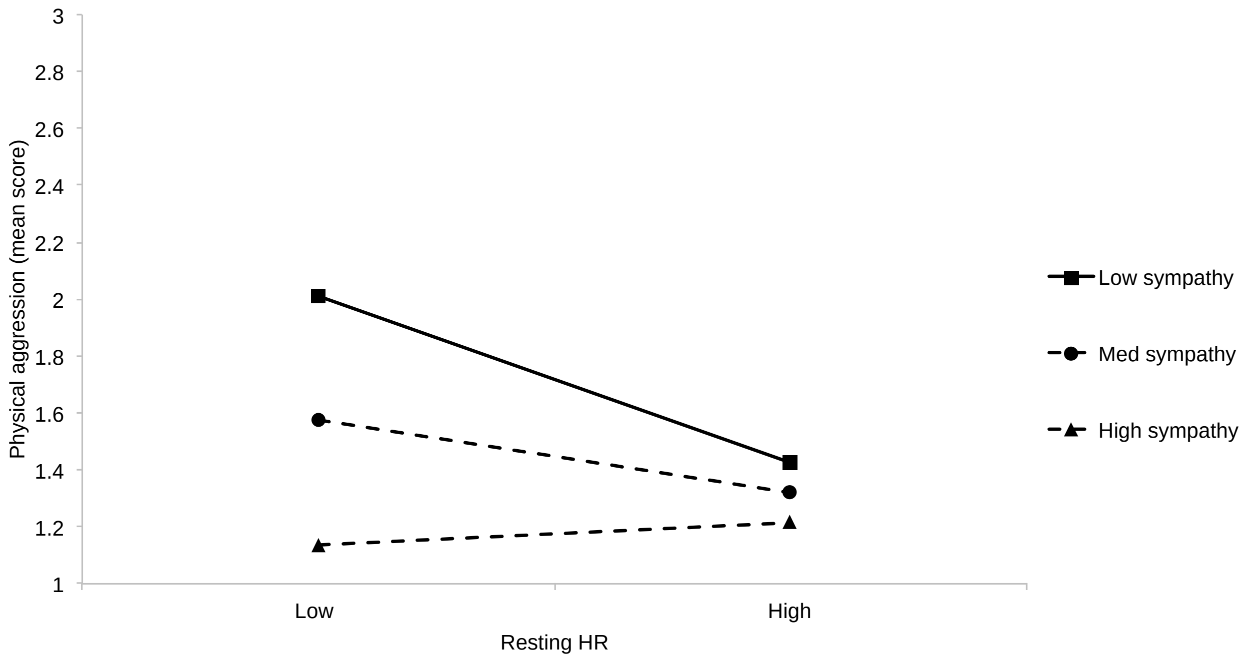

Figure 2. Resting HR in relation to physical aggression for 8-year-olds with low (-1 *SD*), medium, and high (+1 *SD*) ratings of sympathy. Dotted lines represent nonsignificant effects.