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Associations between empathy, inhibitory control, and physical aggression in toddlerhood

Malou M. P. G. Noten[1,2] (iD) | Kristiaan B. Van der Heijden[1,2] | Stephan C. J. Huijbregts[1,2] | Stephanie H. M. Van Goozen[1,3] | Hanna Swaab[1,2]

[1]Department of Clinical Neurodevelopmental Sciences, Leiden University, Leiden, The Netherlands

[2]Leiden Institute for Brain and Cognition, Leiden, The Netherlands

[3]School of Psychology, Cardiff University, Cardiff, UK

Correspondence
Malou Noten and Kristiaan van der Heijden, Department of Clinical Neurodevelopmental Sciences, Leiden University, Wassenaarseweg 52, Box 9555, 2300 RB Leiden, The Netherlands.
Email: M.M.P.G.Noten@fsw.leidenuniv.nl (M. N) and KBHeijden@fsw.leidenuniv.nl (K. H)

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Abstract

Impaired empathy has been associated with aggression in children, adolescents and adults, but results have been contradictory for the preschool period. Impaired inhibitory control also increases the risk of aggression, and possibly moderates empathy-aggression associations. The current study investigated whether empathy and inhibitory control are associated with aggression in toddlerhood. Furthermore, we aimed to clarify the role of inhibitory control in empathy and aggression, specifically, whether inhibitory control moderates the association between empathy and aggression. During a laboratory visit at age 30 months (N = 103), maternal reports of physical aggression were obtained and child inhibitory control was examined using a gift delay task. Empathy was examined by obtaining behavioral observations and recording physiological responses (heart rate response and respiratory sinus arrhythmia response) to an empathy-eliciting event (i.e., simulated distress). Reduced inhibitory control was associated with more aggression. Behavioral and physiological indicators of empathy were not associated with aggression. Hierarchical regression analyses revealed an interaction effect of heart rate response to distress simulation with inhibitory control in the prediction of aggression. Post hoc analyses indicated a negative association between heart rate response and aggression when inhibitory control was high, but a positive association was found in toddlers who demonstrated low inhibitory control. These results suggest that children are less aggressive when they have both high levels of empathy and inhibitory control. Therefore, both empathy and inhibition are important targets for interventions aiming to reduce or prevent aggression at a young age.

KEYWORDS
aggression, empathy, heart rate, inhibition, respiratory sinus arrhythmia

1 | INTRODUCTION

Aggression emerges during the first year of life and manifests as physical aggression (e.g., hitting and biting). Physical aggression peaks during the second and third year of life, when virtually all children show physical aggression at least occasionally, and declines during the fourth year of life, when other forms of aggression start to increase (e.g., verbal aggression; Alink et al., 2006;

Hay et al., 2010; Tremblay et al., 1999). Persistently high levels of physical aggression in toddlerhood have been shown to be an important risk factor for aggressive behavior later in development, as approximately one out of six children shows high and stable levels of aggression from toddlerhood to preadolescence (Cote, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006). Physical aggression at age 5–7 years has been shown to be a better predictor of continued problem behavior in adolescence than other types of problem behavior (Broidy et al., 2003). It is important to study the risk factors of aggression early on, as these risk factors may be important targets for preventive interventions (Cote et al., 2006; Tremblay, 2010; Tremblay et al., 2004).

1.1 | Empathy

Impaired empathy has been considered an important risk factor for aggressive behavior (Bons et al., 2013; Jolliffe & Farrington, 2004; Miller & Eisenberg, 1988; Vachon, Lynam, & Johnson, 2014; van Langen, Wissink, van Vugt, Van der Stouwe, & Stams, 2014). Empathy refers to the ability to share and understand feelings of others and is a fundamental component of social competence, which results from a complex interplay between involuntary neurocognitive, neuroendocrine, and autonomic processes (Decety, 2010; Eisenberg, Eggum, & Di Giunta, 2010). Precursors of empathy may already be present at a very early age, as newborns and infants become distressed in response to other infants' crying, but not to recordings of their own crying (Dondi, Simion, & Caltran, 1999; Geangu, Benga, Stahl, & Striano, 2010). In infants and toddlers, empathy-eliciting situations are often emotionally challenging and result in empathic distress, which is a self-oriented response (Eisenberg, 2010; Hoffman, 2000). Empathic distress can manifest as personal distress and seeking comfort, because vicarious emotional responses cannot be regulated and become aversive (Liew et al., 2011; McDonald & Messinger, 2011). In addition to empathic distress, other-oriented empathic concern also occurs in infancy and toddlerhood; it includes concern for the well-being of others and trying to understand the cause of the feelings of the other, and motivates attempts to reduce the other person's distress (Davidov, Zahn-Waxler, Roth-Hanania, & Knafo, 2013; Eisenberg et al., 2010; McDonald & Messinger, 2011). As a result of development in emotion regulation, self-other differentiation and perspective taking during the second and third year of life, toddlers increasingly focus on the other's distress instead of focusing exclusively on their own distress, which results in more empathic concern.

Although behavioral observations are commonly used to examine empathy, they may be influenced by the effect of emotional expressiveness (Zhou, Valiente, & Eisenberg, 2003), and physiological measures can provide indices of empathy that are under less conscious control (Gill & Calkins, 2003; Liew et al., 2003; Miller, Nuselovici, & Hastings, 2016; Schuetze, Eiden, Molnar, & Colder, 2014). Empathic behavior results from a complex interplay between involuntary neurocognitive, neuroendocrine, and autonomic

processes (Decety, 2010). Autonomic arousal in response to emotions of others, such as increased heart rate, is not synonymous with empathy, but is considered to represent a reliable and objective measure of empathy (Bons et al., 2013). Nevertheless, the association between heart rate responses and empathy is complex (Hastings & Miller, 2014; Hastings, Miller, Kahle, & Zahn-Waxler, 2014). Heart rate responses to empathy-evoking situations have been shown to indicate various types of empathic behavior. Heart rate deceleration has been associated with interest and an outward orientation of attention, such as empathic concern, whereas heart rate acceleration has been associated with a self-focus and empathic distress (Eisenberg, 2010; Zahn-Waxler, Cole, Welsh, & Fox, 1995). Empathic distress and empathic concern both result from empathy (sharing and understanding other's feelings) and can occur simultaneously, in particular in young children (Gill & Calkins, 2003; Israelashvili & Karniol, 2018; Liew et al., 2011; Lin & Grisham, 2017; Young, Fox, & Zahn-Waxler, 1999). At this developmental stage, experimental studies have shown increases of heart rate rather than decreases of heart rate in response to empathy-eliciting situations (Gill & Calkins, 2003; Schuetze et al., 2014).

In addition to heart rate, suppression of respiratory sinus arrhythmia (RSA), which is the variability of heart rate during the respiratory cycle that indicates parasympathetic cardiac control, has been shown to be an indicator of arousal regulation during empathy-evoking situations (Gill & Calkins, 2003; Liew et al., 2011; Miller et al., 2016; Schuetze et al., 2014). These studies found better regulation of arousal, as indicated by more RSA suppression, to be associated with less empathic distress and more empathic concern in the preschool period (Liew et al., 2011; Miller et al., 2016; Schuetze et al., 2014). Yet, another study indicated that more RSA suppression was associated with less empathic concern (Gill & Calkins, 2003). Despite the fact that physiological responses to others' emotional states have been used as indicators of empathy, the association between physiological responses and empathy remains complex and more research is necessary to better understand these associations (Hastings & Miller, 2014; Hastings et al., 2014).

1.2 | Empathy and aggression

Impaired empathy has been shown to be a risk factor of aggression in children, adolescents, and adults, but the results have been contradictory in the preschool period (Lovett & Sheffield, 2007). A negative association between empathy and aggression has been found in several studies examining empathy in relation to aggression and hostile behavior (Belacchi & Farina, 2012; Hughes, White, Sharpen, & Dunn, 2000; Strayer & Roberts, 2004). Conversely, positive associations have also been found in boys aged 4–5 years (Feshbach & Feshbach, 1969), and in 2-year-olds (Gill & Calkins, 2003). However, several studies did not find a significant association between empathy and aggression (Macquiddy, Maise, & Hamilton, 1987; Zahn-Waxler et al., 1995). One study did not reveal concurrent associations, but revealed only longitudinal

associations between empathy and aggression from age 4–5 to 6–7 (Hastings, Zahn-Waxler, Robinson, Usher, & Bridges, 2000). However, no significant results were found in another study from age 14–36 months to 4–17 years (Rhee et al., 2013). Therefore, it remains unclear whether empathy and aggression are already associated in the preschool period.

1.3 | Inhibitory control

Impaired inhibitory control is another factor that has been considered a risk factor for aggressive behavior. Inhibitory control refers to the conscious regulation of behavior, in particular the suppression of behavior to initiate less favorable behavior (Kochanska, Murray, & Coy, 1997; Kochanska, Murray, & Harlan, 2000). Inhibition develops rapidly in the preschool period. Simple inhibitory control, such as inhibiting motor responses, starts to develop from the first year of life and increases over time, whereas more complex inhibition skills, such as inhibition tasks that involve working memory, develop from age 3 years (Carlson, 2005; Garon, Bryson, & Smith, 2008; Kochanska et al., 2000). Various studies indicated that poor inhibitory control is associated with high levels of aggressive behavior during the preschool period (Hughes et al., 2000; Raaijmakers et al., 2008; Waller, Hyde, Baskin-Sommers, & Olson, 2017). Impairments in inhibitory control have been proposed to explain the contradictory effects and null-findings regarding the association between empathy and aggression in the preschool period (Eisenberg, 2010; Eisenberg et al., 2010; Gill & Calkins, 2003; Lovett & Sheffield, 2007). Possibly, a lack of inhibitory control leads to impulsive behavior (e.g., approaching the other) in both empathy- and aggression-evoking events in toddlerhood (Gill & Calkins, 2003). Under conditions of impaired (or not yet sufficiently developed) inhibitory control, both empathic and aggressive behavior may be expected to be high (i.e., a positive association between empathy and aggression), whereas high inhibitory control could result into more empathy and less aggression (i.e., a negative association between empathy and aggression).

1.4 | The current study

The aim of the current study was to investigate whether empathy and inhibitory control are associated with aggression in toddlerhood. We hypothesized that higher levels of physical aggression would be associated with less empathy, as indicated by less empathic concern and empathic distress, and a reduced increase in heart rate and reduced RSA suppression in response to an empathy-eliciting event (Belacchi & Farina, 2012; Strayer & Roberts, 2004). In addition, higher levels of aggression were hypothesized to be associated with lower levels of inhibitory control (Hughes et al., 2000; Raaijmakers et al., 2008; Waller et al., 2017).

In addition to the association of empathy and inhibitory control with aggression, we aimed to investigate whether inhibitory control moderates the association between empathy and aggression. Negative associations between indicators of empathy (i.e., empathic distress,

empathic concern, heart rate increase, and RSA suppression in response to an empathy-eliciting event) and aggression were hypothesized to be present for toddlers showing better inhibitory control. In contrast, lower levels of inhibitory control were hypothesized to be associated with positive associations between empathy and aggression.

2 | METHODS

2.1 | Participants

The present study is part of the Mother-Infant Neurodevelopment Study in Leiden, The Netherlands (MINDS-Leiden). MINDS-Leiden is an ongoing longitudinal study into neurobiological and neurocognitive predictors of early behavior problems. The study was approved by the ethics committee of the Department of Education and Child Studies at the Faculty of Social and Behavioural Sciences, Leiden University (ECPW-2011/025), and by the Medical Research Ethics Committee at Leiden University Medical Centre (NL39303.058.12). Women (N = 153) were recruited during pregnancy and signed informed consent. Primiparous women aged between 17 and 25 years (M = 23.62, SD = 2.03) were eligible to participate. Women with severe complications during pregnancy and women who could not speak or understand the Dutch language were excluded from participation. The MINDS-Leiden study oversampled on high-risk backgrounds, which increased variance in maternal and child's behavior (see Smaling et al., 2015 for detailed procedures). The data for the current study were collected during a laboratory visit 30 months post-partum, which was the fifth data wave of MINDS-Leiden. In this data wave, 103 mother–child dyads were included (M_{age} = 30.46 months, 53.4% males). In most cases, dropout (n = 50) was due to unwillingness to participate without further motivation, unreachability and health issues of the mother. Four mothers could not visit the laboratory but did fill out the questionnaire regarding physically aggressive behavior at home and returned it by mail. Dropout was unrelated to maternal factors such as level of education, ethnicity, and marital status. All participants were given a reimbursement for their time and travel expenses and the children received a gift at the end of the appointment.

2.2 | Procedure

A laboratory visit was scheduled at a time of day that mother estimated the child would be most alert (n = 103). After some time to familiarize with the laboratory and the experimenters, the cardiac monitoring equipment was attached to the child. Subsequently, the children watched a video clip for 2 min in order to measure baseline heart rate and RSA. The baseline condition consisted of a 5-min age-appropriate movie clip. For each child, two consecutive minutes were selected during which the child was most relaxed and attended the movie clip, and few or no artifacts were present. The duration of the baseline was based on previous research indicating appropriate baseline periods between 2 and 5 min (Benevides & Lane, 2015; de

Geus, Willemsen, Klaver, & van Doornen, 1995; Willemsen, DeGeus, Klaver, VanDoornen, & Carroll, 1996). Immediately after the baseline, an empathy-eliciting event occurred, which was followed by a break to allow the children to recover from the event. Inhibitory control was assessed at the end of the laboratory visit because this task includes a gift for the child to take home.

2.3 | EMPATHY

Empathy was assessed by a distress simulation task adapted from Zahn-Waxler, Radke-Yarrow, Wagner, and Chapman (1992). The experimenter asked the mother to refrain from interacting with the child and the child was seated in a chair in order to reduce movement artifacts in the physiological data. Subsequently, the experimenter pretended to hurt her toe by bumping into a piece of furniture and performing a 1-min distress simulation. To maintain attention of the children for 1 min and to create an authentic distress simulation, the experimenter pretended to be in pain for 30 s and to slowly recover from the pain for another 30 s. The pain simulation consisted of the experimenter sitting down on the floor while rubbing her foot, and expressing pain vocally, but she did not make eye contact with the child.

Behavioral responses of the child were videotaped by a second experimenter and coded for the two dimensions of empathic distress: comfort seeking (0; does not seek comfort with self or mother - 4; self-comforting behavior for nearly the whole task and high levels of proximity to mother by "flying" onto the mother's neck) and personal distress (0; no distress – 3; whimpers, whines, or cries; see Noten et al., 2019 for a detailed description of the coding procedure). In addition, three dimensions of empathic concern were coded: concerned expressions (0; no concern – 3; strong facial concern for at least 8 s), testing hypotheses (0; no hypothesis testing – 4; four or more combined gestures and verbal inquires to understand the situation), and prosocial behavior (0; no prosocial behavior – 3; assisting the experimenter by comforting or sharing toys for more than 5 s; Noten et al., 2019). Two trained coders coded all videos and created one consensus score when their scores differed (ICC of absolute agreement: testing hypothesis = 0.874; prosocial behavior = 0.953; concerned expressions = 0.742; self-distress = 0.839; comfort seeking = 0.782). Based on the results of a categorical principal component analysis of the five empathy scales, the scores on these scales were transformed into standardized scores and averaged into a composite score for empathic distress (comfort seeking and personal distress) and a composite score for empathic concern (prosocial behavior, hypothesis testing, and concerned expressions). Empathy data were missing for one child due to failure of the video equipment.

Physiological parameters were assessed during a 2-min baseline and the 1-min distress simulation task with the Vrije Universiteit Ambulatory Monitoring System (VU-AMS) (De Geus & Van Doornen, 1996; de Geus et al., 1995; Willemsen et al., 1996). The VU-AMS is a portable device, which was attached to the back of the children with a small belt, allowing them to freely move around the room. Seven disposable pre-gelled Ag/AgCl electrodes (ConMed Huggable 1620–001) were attached to the trunk of the child. Electrocardiogram (ECG) and impedance cardiogram (ICG) were continuously measured. ICG measures consisted of thorax impedance (Z0), impedance change (dZ), and the first derivative of impedance change (dZ/dt). The ECG and dZ/dt signal were sampled at 1,000 Hz, and the Z0 signal was sampled at 10 Hz. Mean values of heart rate and RSA across baseline and distress simulation episodes were automatically calculated using VU-DAMS software suite version 3.9, then visually checked by a trained experimenter and adjusted manually if necessary. The peak-trough method was used to compute RSA (de Geus et al., 1995; Grossman, Beek, & Wientjes, 1990), in which the respiration signal, obtained from the filtered (0.1 – 0.4 Hz) dZ signal, and the inter beat intervals (IBI's) are combined to compute the difference between the shortest IBI during inspiration (when heart rate accelerates) and the longest IBI during expiration (when heart rate decelerates; de Geus et al., 1995). Physiological data were missing due to unwillingness to comply with the procedures (n = 7), movement artifacts (n = 1 for heart rate and n = 3 for RSA), loose electrodes (n = 2), and failure of the VU-AMS equipment (n = 1). For heart rate and lnRSA, change scores from baseline to the distress simulation were calculated in such a way that positive difference scores indicate responses in the expected direction (increased arousal as indicated by increase of heart rate and decrease of lnRSA).

2.4 | INHIBITORY CONTROL

Inhibitory control was measured by a gift delay task, which has been shown to provide a valid measure of inhibitory control in a motivational setting (i.e., the child can earn a reward) at age 30 months (Kim, Nordling, Yoon, Boldt, & Kochanska, 2013; Kochanska et al., 2000). At the end of the laboratory visit, the experimenter put a colorful gift box on a table in front of the child. Subsequently, the experimenter started a countdown to open the box, but halfway the experimenter suddenly remembered she forgot something and said that she would be right back. The experimenter left the room for 3 min and asked the child to not to open the gift until she was back. The mother of the child was seated in a corner of the room to fill out some questionnaires and she was asked not to respond or to respond neutrally to the child during the task. Upon return of the experimenter, the child was rewarded for waiting and invited to open the gift (if the gift had not been opened yet). Latency to touch the gift box was coded 0 (touches the box immediately), 1 (waits between 2 and 60 s) or 2 (waits longer than 60 s) and behavior during the task was coded 0 (the child opens the box and grabs the gift), 1 (the child peeks in the box), 2 (the child touches the box but does not open it), or 3 (the child does not touch the box). Given high correlations between latency and behavior measures (r (99) = 0.535, p = <.001), the two measures were transformed to z-scores and averaged into one inhibition score (Kim et al., 2013; Kochanska et al., 2000). Data were missing for one child because the child was too fussy to comply with the task and

the latency score was missing for three children due to failure of the video equipment.

2.5 | Physical aggression

All participating mothers completed the Dutch version of the Physical Aggression Scale for Early Childhood (PASEC) to measure physical aggression. The PASEC has been shown to be a valid measure of physical aggression in toddlerhood (Alink et al., 2006). The questionnaire consisted of 11 items that were scored on a 3-point Likert scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true), for example bites others, hits others, and destroys his own things. Scores were summed up to create one physical aggression score (Cronbach's α = 0.77).

2.6 | Data analyses

All variables were checked for outliers and violations of assumptions. Measurements that were three standard deviations above or below the average were replaced with the closest value within this range (n = 1 for heart rate and n = 1 for RSA). The natural logarithm of RSA and the PASEC was used because these variables were positively skewed before transformation. Baseline levels of heart rate and lnRSA were used as covariates in the analyses concerning physiological responses to control for differences in baseline arousal levels. To check whether a physiological reaction was present from baseline to the simulated distress episode, paired sample t-tests were conducted. A categorical principal component analysis was performed on the five scales of the empathy observations to examine whether the empathic distress and empathic concern dimensions were indeed present in our data. Pearson correlations were performed to examine the associations between aggression, inhibitory control, heart rate response to simulated distress, RSA response to simulated distress, and the scales for empathic distress and empathic concern. Correlations with heart rate response and lnRSA response were controlled for baseline heart rate and baseline lnRSA respectively. Point-biserial correlation analyses were performed to assess the effect of sex. The main and interaction effects of empathy and inhibitory control on physical aggression were examined by four hierarchical linear regression analyses. One for each indicator of empathy: empathic distress, empathic concern, heart rate response, and lnRSA response to distress simulation. Control variables (sex, baseline heart rate, baseline lnRSA), the main effect of empathy indicators, and the main effect of inhibitory control on physical aggression were entered in the first step, and the interaction between empathy indicators and inhibitory control was added in the second step of the regression analysis. All variables were centered in advance and interaction effects were further examined by plotting the effect of the independent variable on the dependent variable at different levels (−1SD, mean, and + 1SD) of the moderator (Aiken, West, & Reno, 1991; Holmbeck, 2002). All analyses were done using the Statistical Package for Social Sciences

(SPSS for windows, version 23, SPSS Inc., Chicago) and statistical significance was set at $p < .05$ a priori.

3 | RESULTS

3.1 | Preliminary analyses

Characteristics of the sample are shown in Table 1. Maternal characteristics were not related to any of the child variables, except for a significant negative association between maternal educational level and aggression ($r_{spearman}$(103) = −0.258, p = .009). A categorical principal component analysis was conducted on the five behavioral observations during the distress simulation task with orthogonal varimax rotation. Two components had eigenvalues over Kaiser's criterion of 1 and explained 70.79% of the variance in total. Factor loadings confirmed that concerned expressions, hypothesis testing, and prosocial behavior loaded high on a component representing empathic concern, and that comfort seeking and personal distress loaded high on the other component representing empathic distress. All factor loadings and correlations between the behavioral observation scales are presented in supplement 1 and 2.

TABLE 1 Sample characteristics

Variable	%	M(SD)
Mother		
Caucasian ethnicity	89.3%	
Highest education completed		
Secondary education	7.8%	
Tertiary education	55.3%	
Bachelor degree or higher	36.9%	
Child		
Sex (male)	53.4%	
Age (months)		30.46 (0.78)
Heart rate, baseline		110.91 (10.97)
Heart rate, distress simulation		113.17 (12.36)
lnRSA, baseline		3.92 (0.55)
lnRSA, distress simulation		3.85 (0.64)
Empathic behavior		
Prosocial behavior (0–3)		0.56 (1.13)
Hypothesis testing (0–4)		1.72 (1.07)
Concerned expressions (0–3)		1.39 (1.18)
Personal distress (0–3)		0.85 (0.76)
Comfort seeking (0–4)		1.12 (0.99)
Inhibitory control		
Latency to touch (0–2)		0.96 (0.73)
Behavior (0–3)		1.46 (0.95)
Physical aggression		2.59 (2.42)

Note: Natural log of respiratory sinus arrhythmia (lnRSA).

Paired sample *t*-tests indicated that heart rate increased ($t(91) = 3.172$, $p = .002$, $d = 0.19$) and lnRSA decreased ($t(89) = 2.197$, $p = .031$, $d = 0.12$) from baseline to the distress simulation episode. Correlations between behavioral and physiological responses to the distress simulation, inhibitory control, and aggression are shown in Table 2. Point-biserial correlation analyses indicated that aggression was higher and inhibitory control was lower in boys compared to girls. In addition, Pearson correlation analyses demonstrated that higher levels of aggression were associated with lower baseline heart rate and higher baseline lnRSA. A larger increase in heart rate in response to the distress simulation task was associated with a larger decrease in lnRSA, more empathic concern, and more empathic distress.

3.2 | Empathy and inhibitory control in relation to aggression

Pearson correlations indicated that higher levels of aggression were associated with lower levels of inhibitory control. However, no significant associations were found between aggression and any behavioral or physiological responses to the distress simulation task. The results of the regression analyses on the effects of indicators of empathy and inhibitory control on aggression are shown in Table 3 and Table 4. A main effect was present for baseline heart rate and baseline lnRSA, but not for responses to empathic situations or inhibitory control on aggression. In addition, an interaction effect of heart rate response to the distress simulation task with inhibitory control was present in the prediction of aggression. In order to be able to interpret the interaction effects, the regression lines of low (–1 *SD*), moderate (0 *SD*), and high (+1 *SD*) empathy and inhibitory control are plotted in Figure 1.

Regarding heart rate response during the distress simulation, a significant positive effect was shown at low levels of inhibitory control ($\beta = 0.362$, $t = 2.514$, $p = .014$), no effect was shown at mean levels of inhibitory control ($\beta = -0.021$, $t = -0.201$, $p = .834$), and a significant negative effect was found at high levels of inhibitory control ($\beta = -0.273$, $t = -1.993$, $p = .050$).

4 | DISCUSSION

This study aimed to investigate whether empathy and inhibitory control are associated with aggression in toddlerhood. We expected higher levels of physical aggression to be associated with less inhibitory control and less empathy, as indicated by less empathic concern, less empathic distress, smaller increase of heart rate, and less RSA suppression in response to an empathy-eliciting event. In addition, we aimed to investigate whether inhibitory control moderates the association between empathy and aggression. Negative associations between indicators of empathy (i.e., empathic distress, empathic concern, heart rate increase, and RSA suppression in response to an empathy-eliciting event) and aggression were hypothesized to be present for toddlers showing higher levels of inhibitory control. In contrast, lower levels of inhibitory control were hypothesized to be associated with positive associations between empathy and aggression.

The results were partly consistent with the hypotheses. In contrast to our hypotheses, no association was present between any of the indicators of empathy and aggression. A negative association was found between inhibitory control and physical aggression, which is in line with our hypotheses. Previous studies also found negative associations between inhibitory control and aggression in the preschool period (Hughes et al., 2000; Raaijmakers et al., 2008; Waller et al., 2017). Therefore, deficits in inhibitory control may contribute to the development of aggression over time, and improving inhibition may be an important target for interventions aiming to prevent

TABLE 2 Correlations between behavioral and physiological responses to the distress simulation, inhibitory control, and physical aggression

	2	3	4	5	6	7	8	9
1. Sex	−0.216*	0.180	0.233*	−0.073	−0.053	−0.028	0.071	0.026
2. lnPASEC	—	−0.218*	−0.231*	−0.026	0.276**	0.014	0.027	0.152
3. Inhibitory control		—	−0.056	0.122	0.043	0.162	0.155	−0.168
4. Heart rate baseline			—	−0.096	−0.736**	0.090	−0.167	0.082
5. Heart rate response				—	−0.134	0.614**	0.322**	0.284**
6. lnRSA baseline					—	0.029	0.177	−0.079
7. lnRSA response						—	0.128	−0.018
8. Empathic distress							—	0.101
9. Empathic concern								—

Note: Natural log of respiratory sinus arrhythmia (lnRSA). Higher scores indicate more, aggression, inhibitory control, and empathy. Positive heart rate and lnRSA responses represent responses in the expected direction (increase of heart rate and decreases of lnRSA). Pearson correlations with heart rate response and lnRSA response are controlled for baseline levels of heart rate and lnRSA, respectively.
*$p \leq .05$; **$p \leq .01$.

TABLE 3 Regression analyses of main and interaction effects of behavioral responses to distress simulation and inhibitory control on physical aggression

	B	t	R^2 change	Sig.	β	t	R^2 change	Sig.
	Empathic distress				**Empathic concern**			
Step 1			.085	0.037			.096	0.022
Sex	−0.185	−1.856		0.067	−0.190	−1.910		0.059
Empathic response	0.071	0.712		0.478	0.129	1.305		0.195
Inhibitory control	−0.196	−1.945		0.055	−0.163	−1.615		0.110
Step 2			.007	0.410			.003	0.561
Sex	−0.183	−1.827		0.071	−0.189	−1.895		0.061
Empathy	0.088	0.862		0.391	0.123	1.229		0.222
Inhibitory control	−0.198	−1.958		0.053	−0.150	−1.452		0.150
Empathy × Inhibitory control	−0.83	−0.838		0.410	−0.059	−0.583		0.561

TABLE 4 Regression analyses of main and interaction effects of physiological responses to distress simulation and inhibitory control on physical aggression

|	B	t	R^2 change	Sig.	β	t	R^2 change	Sig.
	Heart rate				**lnRSA**			
Step 1			.122	0.024			.157	0.006
Sex	−0.130	−1.211		0.229	−0.162	−1.580		0.118
Baseline	−0.213	−2.026		0.046	0.275	2.725		0.008
Empathic response	−0.010	−0.092		0.927	0.042	0.412		0.681
Inhibitory control	−0.206	−1.962		0.053	−0.208	−1.998		0.049
Step 2			.093	0.002			.031	0.079
Sex	−0.208	−1.986		0.050	−0.207	−1.983		0.051
Baseline	−0.201	−2.007		0.048	0.276	2.762		0.007
Empathy	0.021	0.201		0.834	0.072	0.700		0.486
Inhibitory control	−0.140	−1.378		0.172	−0.187	−1.803		0.075
Empathy × Inhibitory control	−0.320	−3.146		0.002	−0.186	−1.778		0.079

Note: Natural log of respiratory sinus arrhythmia (lnRSA); positive heart rate and lnRSA responses represent responses in the expected direction (increase of heart rate and decreases of lnRSA).

or reduce aggressive behavior in early childhood (Raaijmakers et al., 2008).

In line with our hypotheses, inhibitory control moderated the effect of heart rate responses to an empathy-evoking event on aggression. A negative association between heart rate response to distress simulation and aggression was present in children who showed good inhibitory control, whereas a positive association was present at lower levels of inhibitory control. The lowest aggression scores were found in children with good inhibitory control and high levels of empathy. This in line with the underlying mechanism of the association between empathy and aggression as theorized in the violence inhibition model (Blair, 1995). This model proposes that children connect their own experience of negative emotions (e.g., when the child experiences pain) to the experience of others in similar situations and label these experiences as undesired. Subsequently, the child acts to prevent or reduce these

experiences in others by responding empathically and inhibiting aggressive behavior. Adequate inhibition skills are a prerequisite for this mechanism to function optimally. Therefore, better inhibition skills could be expected to result in a negative association between empathy and aggression. The positive association between empathy and aggression in children with lower inhibitory control corresponds to the proposition that a lack of inhibition leads to impulsive responses to both empathy- and aggression-evoking events (Gill & Calkins, 2003). Therefore, differences between previous findings on the association of empathy and aggression in toddlerhood may be explained by heterogeneity within samples of children regarding inhibition (Eisenberg et al., 2010; Gill & Calkins, 2003; Lovett & Sheffield, 2007). Future research on empathy and aggression in toddlerhood could benefit from taking inhibition into account.

Furthermore, more research is necessary to further examine the differences between indices of empathy, as no association between
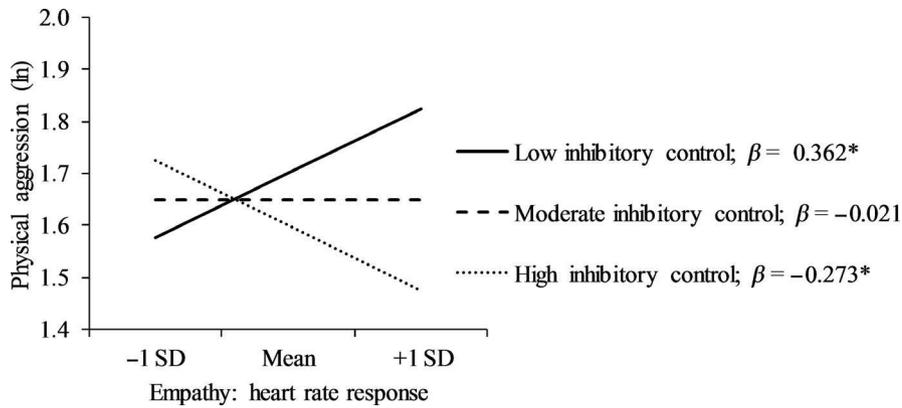
FIGURE 1 Interaction effect of heart rate response and inhibitory control on physical aggression

empathy and aggression was found for lnRSA response, empathic concern, and empathic distress. The lack of significant results for the behavioral measures of empathy is in line with recent findings that 8- to 12-year-old children at risk of criminal behavior (children with delinquent siblings or parents) were found to have reduced heart rate responses to empathy-evoking video clips compared to typically developing controls, whereas no effects were found for social attention or self-reported empathy (van Zonneveld, Platje, de Sonneville, van Goozen, & Swaab, 2017). These results support the suggestion that objective physiological measures of empathy are more likely to result into positive findings than behavioral observations (Bons et al., 2013; Zhou et al., 2003). A possible explanation for the lack of results regarding RSA suppression might be that RSA suppression was not only affected by the empathy-eliciting situation, but also by inhibition. Previous studies indicate that RSA can be considered a biomarker for self-regulation, which includes inhibition (Holzman & Bridgett, 2017; Obradović, 2016; Skowron, Cipriano-Essel, Gatzke-Kopp, Teti, & Ammerman, 2014). Therefore, the influence of inhibition on RSA suppression may have confounded the association between RSA suppression in response to distress simulation and aggression. Heart rate is considered a general measure of arousal and therefore may have been a better indicator of empathy in the current study.

Of note, our results indicate that a stronger increase in heart rate during the empathy-eliciting situation was related to more empathic distress and higher empathic concern. Previous studies in older children indicate that a stronger increase in heart rate was related to more empathic distress but less empathic concern (Eisenberg, 2010; Zahn-Waxler et al., 1995). The inconsistency between our findings regarding empathic concern and previous findings might be caused by the fact that physiological responses were measured during a distress simulation task in the current study, whereas previous studies used a milder emotion induction (i.e., emotional video clips). During more intense emotion inductions, empathic distress and empathic concern may occur simultaneously. In those instances, heart rate responses may be indicative of both empathic distress and empathic concern. Possibly, simultaneous occurrence of empathic distress and empathic concern resulted in the similar direction of effects of heart rate responses on empathic distress and empathic concern in the current study (Zhou et al., 2003).

The results of this study emphasize the importance of specifically considering inhibitory control as a moderating factor when examining empathy-aggression associations in toddlerhood. No association was present between inhibitory control and empathy and it remains unclear whether such an association is already present in toddlerhood. Some behavioral studies on toddlers have shown a negative association between inhibited temperament (fearfulness) and empathy (Liew et al., 2011; Mark, Ijzendoorn, & Bakermans-Kranenburg, 2002; Young et al., 1999), whereas studies in older children suggest positive associations between inhibitory control and empathic concern (Eisenberg, 2010; Eisenberg et al., 2007). Further research is necessary to elucidate this association.

4.1 | Strengths and limitations

The current study adds to the literature by examining empathy both behaviorally and physiologically, which provides valuable information on toddler's responses to empathy-eliciting events. Furthermore, both empathic distress and empathic concern were coded and the factors were confirmed by principal component analysis. A limitation is that maternal reports were used to examine aggression in toddlerhood. Parent reports provide ecologically valid information about behavior in daily situations that toddlers cannot report themselves and are difficult to capture during observations (Lorber, Del Vecchio, & Slep, 2018). In addition, the PASEC has shown to be a reliable and valid measure of physical aggression in toddlerhood and previous studies showed that physical aggression was a better predictor of continued problem behavior than other domains of problem behavior, such as nonaggressive conduct problems and oppositional behaviors (Alink et al., 2006; Broidy et al., 2003). Nevertheless, it should be noted that maternal reports of aggression might be biased by maternal factors such as personality, memory capacity, and tendency of social desirability response (Kagan, Snidman, Arcus, & Reznick, 1994).

A second limitation is that the distress simulation was performed by the experimenter rather than by the child's mother in order to reduce bias caused by differences in the credibility and intensity of the distress simulation. Although this strengthens the reliability of the empathy measure, a limitation is that distress in unfamiliar people evokes less empathic concern in toddlers compared to when

distress is expressed by their mothers (Knafo, Zahn-Waxler, Van Hulle, Robinson, & Rhee, 2008; Preston & de Waal, 2002; Young et al., 1999). Therefore, our setup may have limited the children's empathic concern, resulting in low variance on prosocial behavior. In addition, the brief duration of the distress simulation to maintain children's attention may have affected the reliable and valid collection of physiological indices of empathy.

The impact of the inhibition task may have been limited by the presence of the mother in the room. Parental involvement has been shown to be associated with children's performance on the gift delay task at age 2–3 years (Russell, Londhe, & Britner, 2012). Further research could benefit from including observations of parental behavior as covariate or by asking parents to leave the room. A final limitation is the cross-sectional design of the study. Future research should examine whether empathy and inhibition are predictors of aggression over time and to what extend these associations change over the course of development. When using longitudinal designs, further research should also take Theory of Mind into account, which refers to the ability to attribute mental states to others and understand that others' mental states, desires, and beliefs might differ from one's own. Theory of Mind develops rapidly from the age of four and is closely related to the development of cognitive aspects of empathy (i.e., understanding other's emotions) and executive function, including inhibition, at this age (Carlson, Mandell, & Williams, 2004; Decety, 2010). Furthermore, taking the perspective of the other in empathy-evoking situations, which is a cognitive aspect of empathy and requires Theory of Mind, is an important factor for future research; it also inhibits aggression by reducing the impulse to respond aggressively and enhancing reflective thinking about the situation (Richardson, Hammock, Smith, Gardner, & Signo, 1994).

5 | CONCLUSION

This study showed that inhibitory control, but not empathy, is negatively associated with aggression in toddlerhood. In addition, inhibitory control moderated the effect of heart rate response to an empathy-eliciting situation on aggression. Higher levels of empathic responses were associated with lower levels of aggression, but only if inhibitory control was good, which indicates that high empathy combined with high inhibitory control is associated with lower levels of aggression. When inhibitory control was relatively poor, higher levels of empathic responses were associated to higher levels of aggression, reflecting impulsive responses to both empathy- and aggression-evoking situations. Since empathy and inhibition develop rapidly during toddlerhood, it is important for future studies that investigate their relations with aggression to adopt longitudinal designs. Furthermore, toddlerhood would be a particularly interesting period for further research on the effects of interventions aiming to reduce or prevent aggression by targeting empathy and inhibition.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Malou M. P. G. Noten [iD] https://orcid.org/0000-0002-5963-5057

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.