Physiological reactivity to fear moderates the relation between parenting distress with conduct and prosocial behaviors

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EMPIRICAL ARTICLE

CHILD DEVELOPMENT

Physiological reactivity to fear moderates the relation between parenting distress with conduct and prosocial behaviors

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Abstract

This study investigated whether the associations between parental distress with conduct problems (CPs) and prosocial behaviors (PBs) are moderated by children's skin conductance (SC) and heart rate (HR) reactivity to fear. Participants were 147 Greek-Cypriot children (M_{age} = 7.30, 44.2% girls), selected from a larger screening sample (data were collected from 2015 to 2018). Longitudinal associations suggested that children with high HR reactivity to fear were more likely to display PB, whereas those with low SC reactivity were more likely to engage in CP behaviors. In contrast, interaction effects suggested that children high on SC reactivity to fear were more susceptible to the effects of parental distress, as indicated by their higher vulnerability to engage in CP (cross-sectionally) behaviors and their lower scores on PB (cross-sectionally and longitudinally).

INTRODUCTION

In the past decades, a substantial body of psychophysiological evidence contributed to a better understanding of the neurophysiological mechanisms leading to the development of conduct problems (CP; i.e., oppositionality, defiance, aggressiveness, lying) and prosocial behaviors (PBs; i.e., considerate, caring, kind, helpful; e.g., Eisenberg et al., 2019; Schoorl et al., 2016; Sijtsema et al., 2013). Moving beyond direct associations, interaction models have also shown that children's physiological reactivity to emotional stimuli modulates the impact of several familial factors, including parental mental health, parenting strategies, and marital conflict, on children's behavioral outcomes (Erath et al., 2009; Gao et al., 2017; Hinnant et al., 2019; Philbrook et al., 2018; Sijtsema et al., 2013). Understanding how environmental experiences and physiological mechanisms interact to shape prosocial and CP behaviors, which are indicators of social adjustment and maladjustment, respectively, would greatly influence intervention and prevention strategies for high-risk children.

The current study considers children's physiological responses to fearful stimuli along with parental-related distress in predicting both PB and CP in children aged 5–9 years old. The investigation of such physiological responses early in development may uncover individual etiological factors associated with distinct behavioral outcomes. From a developmental perspective, impairments in processing and responding to fearful stimuli, which is a core feature of socialization (Thompson et al., 2020), can inhibit children's prosocial moral development, leading to CP and other maladaptive behavioral outcomes (Fanti, 2018 for the review; Fanti et al., 2016; Sijtsema et al., 2013). In addition to direct effects, the current study is expected to provide novel evidence as

Abbreviations: CP, conduct problem; PB, prosocial behavior; SC, skin conductance; HR, heart rate; SDQ, Strengths and Difficulties Questionnaire; ECBI, Eyberg Child Behavior Inventory; ECG, electrocardiography.

to whether children's autonomic reactivity to fear exacerbates or attenuates the effects of parental distress on CP and PB, testing the moderating role of physiological reactivity.

Importance of physiological reactivity

Over the past years, the interest in neurophysiological indicators of problematic and PBs has increased substantially, with several studies focusing on heart rate (HR) and skin conductance (SC) reactivity to aversive stimuli in children (see the meta-analysis by Fanti et al., 2019). Both SC and HR are activated in response to stressful or threatening experiences and prepare the body for "flight or fight" responses (Beauchaine, 2001; Lorber, 2004). As such, HR and SC are considered stress regulating indicators and have been used to index individual differences in emotional responses early in life (El-Sheikh et al., 2007). In addition, assessing such physiological markers is essential because they reflect the sensitivity by which individuals react to environmental conditions, and these reactions can influence their prosocial and antisocial interactions (Porges, 2007).

The majority of prior work link CP with reduced SC and HR reactivity to aversive stimuli and stressful conditions, which are biological indicators of fearlessness and insensitivity to punishment (e.g., Fanti, 2018; Raine, 2002; Sijtsema et al., 2013). It has been suggested that in order to optimize their low arousal levels, which represent an unpleasant physiological state, individuals with CP might seek stimulation or novelty by engaging in antisocial acts (Frick & Morris, 2004; Raine, 2002). While the majority of studies report hypo-arousal in response to negative emotional stimuli (e.g., sadness, fear) or stressful tasks among children with CP, additional work point to heightened physiological arousal to aversive stimuli (see meta-analyses by Fanti et al., 2019; Lorber, 2004). This line of work suggests that over-sensitivity toward threatening, fearful and stressful events is related to behavioral dysregulation, which may result in increased CP during childhood (Fanti et al., 2019; Frick & Morris, 2004; Van Goozen et al., 2007). Thus, although evidence from several studies shows irregularities in HR and SC for children with CP, these studies suggest that CP may develop via opposing physiological mechanisms, associated with either hypo-arousal or hyper-arousal in response to negative stimuli or stressful tasks.

Compared to the literature on CP, less work has investigated physiological correlates of PB (Hastings & Miller, 2014). For example, high HR reactivity to others' distress and sadness has been associated with empathic concern and higher levels of PB, whereas lower levels of HR reactivity were associated with CP in preschool children (Zahn-Waxler et al., 1995). Likewise, in a sample of adolescents, elevated HR reactivity to a stress task was identified as a protective factor associated with decreased CP behaviors and enhanced PB (Sijtsema et al., 2013). In a more recent study, children with higher HR reactivity in response to sad emotions were more likely to be characterized by PB compared to children who evidenced relatively low HR reactivity (Coulombe et al., 2019). A prior study with college students suggested that only increased HR reactivity to empathy-related emotions, but not SC reactivity predicted PB (Oliveira-Silva & Gonçalves, 2011). The current study will be the first to investigate the differential effects of SC and HR reactivity to fear stimuli as well as their interactions with parenting distress in predicting PB early in development.

Importance of parental distress

Parental distress refers to the psychological well-being of parents in relation to the demands and restrictions associated with parenting a child (Abidin & Brunner, 1995). As such, parental distress is an important risk factor associated with increased CP (Barry et al., 2005; Fanti & Munoz Centifanti, 2014; Gao et al., 2017). Findings from studies investigating parent–child interactions confirm that distressed parents are more likely to engage in harsh parenting and exhibit less consistent or ineffective parenting skills, leading to the development of disruptive behavior (Erath et al., 2009; Le et al., 2017). In addition, parent–child interplay characterized by distress can lead to coercive exchanges between the dyad, often influencing the child's emotion regulation, behavioral outcomes, and associated stress reactivity to emotional stimuli (Morris et al., 2017).

Prosocial behavior, which includes prosocial motives and empathic actions to benefit others, is enhanced under supporting familial conditions and positive parental emotional states (Eisenberg et al., 2006; Krevans & Gibbs, 1996). Lower parental distress levels are generally linked to positive parent–child interactions as well as children's social adaptation (Flannery et al., 1993), both of which correlate with children's prosocial development (Davidov & Grusec, 2006; Eisenberg et al., 2006). This means that disruptive behaviors between parents and children are minimized when there is an exchange of positive expressivity and empathy within the dyad. In addition, the child is more engaged in the social environment and displays more PB in the family context early in development (Garner et al., 1994). However, parental distress and non-compassionate parenting can act as risk factors for impaired emotional sensitivity of children later in life (Miller & Hastings, 2019).

Overall, prior work suggests that parental distress may be linked with CP and PB via several experiential mechanisms, such as ineffective and inconsistent parenting. Thus, exploring sensitivity to parental distress and how it may impact children's development is of major importance for understanding adaptive and maladaptive functioning. However, a question that remains is whether parental distress differentially influences children's CP and PB based on the child's physiological functioning in an interaction model. Impaired emotional processing and physiological reactivity might be important individual characteristics that may influence such developmental outcomes.

Parenting by physiological reactivity interactions

The diathesis–stress model proposes that disorders result from the interaction between environmental stressors and an individual's biological predispositions (Heim & Nemeroff, 1999). Moreover, the model suggests differential susceptibility to environmental experiences, with some children being less and others being more (i.e., vulnerability) affected by such experiences (Boyce & Ellis, 2005; Kochanska et al., 2015). Only a few studies have examined the interactions between environmental factors and autonomic reactivity in predicting CP in youth and less so in examining PB (e.g., Buodo et al., 2013; Miller & Hastings, 2019). Moreover, prior studies resulted in contradicting findings as to whether high or low levels of physiological reactivity influence children's susceptibility to adverse environmental experiences (Erath et al., 2009; Hinnant et al., 2019; Philbrook et al., 2018; Raine, 2002). For example, prior work found that heightened SC reactivity in response to stress or parental arguments increased the effects of marital conflict and parental depression on CP behaviors (Cummings et al., 2007; El-Sheikh, 2005; El-Sheikh et al., 2007; Philbrook et al., 2018). Although these findings indicate that high SC reactivity is a vulnerability factor that exacerbates the effects of negative familial experiences on CP behaviors, additional work suggested that the association between both positive and negative aspects of parent–child socialization were more strongly associated with CP behaviors among children with low SC levels and low reactivity to stress (Erath et al., 2009; Hinnant et al., 2019; Kochanska et al., 2015). Similarly, parental distress increased the risk of CP among children with low SC reactivity to an aggregate of positive and negative emotional stimuli (Buodo et al., 2013).

One possibility is that SC reactivity might function as a physiological marker indexing either high or low sensitivity to environmental experiences, accounting for the variability identified in associations with CP (Raine, 2002). Children experiencing low SC reactivity to aversive stimuli might not be emotionally sensitive to parenting experiences due to their low arousal levels, low levels of guilt, and insensitivity to punishment associated with fearlessness (Erath et al., 2009; Fanti, 2018). In contrast, according to the biological sensitivity to context theory, high physiological reactivity might relate to elevated sensitivity to social and environmental influences (Belsky & Pluess, 2009; Boyce & Ellis, 2005). Thus, children with high SC reactivity might experience adverse familial incidents or problematic interactions with parents as more aversive due to their fearfulness and increased sensitivity to negative circumstances (Erath et al., 2011; Sijtsema et al., 2013). These results support the equifinality hypothesis, in that different physiological mechanisms, in this case, high or low levels of SC reactivity, interact with negative environmental experiences, which places the child at risk for developing CP.

Although only a few studies tested interactions with HR reactivity to emotional stimuli, existing evidence suggests that HR reactivity in response to laboratory stress tasks can moderate associations between negative familial experiences, such as marital conflict and inconsistent discipline, with CP behaviors (El-Sheikh et al., 2007). One of the few studies investigating interactions between familial variables and HR reactivity to a public speaking task suggested that greater HR reactivity protected adolescents from the effects of low family cohesion on aggression and rule-breaking, while low HR reactivity exacerbated these effects (Sijtsema et al., 2013). The current study investigates whether HR reactivity to fear stimuli also moderates associations between parental distress and CP.

Even fewer studies have tested interactions between physiological reactivity and parenting in relation to PB (Eisenberg et al., 2006; Miller & Hastings, 2019; Sijtsema et al., 2013). Since parents provide learning opportunities to children in terms of how to react or express emotions (Eisenberg et al., 1998), it is highly possible that parents' distressing responses might influence their children's prosocial outcomes. If parents express high levels of distress, children might be more likely to become overaroused by negative emotions, which might contribute to personal distress and, consequently, to low levels of other-oriented PB (Eisenberg et al., 2006; Miller & Hastings, 2019). Agreeing with this suggestion, Sijtsema et al. (2013) found that greater HR reactivity to a public speaking task was associated with increased PB, whereas the combination between low family cohesion and low HR reactivity was associated with the lowest levels of PB. We will examine whether SC reactivity to fear also moderates associations between parenting distress and PB among children.

Current study

The current study focuses on parental distress and children's physiological reactivity, which are robust predictors of behavioral adjustment (Barry et al., 2005; Fanti & Munoz Centifanti, 2014). Specifically, this study will examine whether children's HR and SC reactivity to fear enhances or reduces vulnerability to the detrimental effects of parenting-related distress on CP and PB. This is important because the majority of prior work did not focus on the interaction between parental distress and children's physiological reactivity. Further, we will consider the degree of shared variance between HR and SC reactivity, providing unique evidence in terms of the moderating role of these physiological markers in the association between parental distress with CP and PB.

One limitation of prior work is the use of diverse emotional, cognitive, and stress-inducing tasks, with some studies combining positive and negative affective stimuli. To clarify prior contradicting evidence, the current study focuses on fear stimuli, which is directly related to a child's level of sensitivity to threats (Woodard & Pollak, 2020). By doing so, we will examine if different levels of physiological reactivity to fear moderate the association between parental distress with CP and PB cross-sectionally and longitudinally. It is expected that the interaction between parental distress with the child's SC and HR reactivity to fear can explain deficits in CP; however, it remains unclear whether high or low levels of physiological reactivity to fearful stimuli moderates this association. To inform prior work, the present study aims to explore whether both reduced and enhanced physiological reactivity to fearful stimuli explains the association between parental distress with CP and PB. By doing so, evidence pointing to individual differences in vulnerability to environmental experiences during childhood will be provided. Thus, the current study proposes non-directional hypotheses to test a novel research question, and as such represents a relatively exploratory effort. Finding that children's susceptibility to parental distress varies as a function of their physiological reactivity to fear can inform future intervention efforts, which can be designed to increase children's prosociality and adaptability by targeting impaired emotional processing toward threats.

Finally, we account for the effects of sex and age (5–9 age range). Taking sex differences into account is important because girls are more likely to view aversive pictures as unpleasant and exhibit greater autonomic reactivity compared to boys (Beauchaine et al., 2008; Sharp et al., 2006). In addition, girls are more prosocial and less antisocial than boys (Fanti & Henrich, 2010; Xiao et al., 2019). Regarding age, older children tend to show increased arousal to unpleasant pictures than younger children (Sharp et al., 2006). Moreover, compared to children, preschoolers may not have fully developed socioemotional abilities (i.e., empathy) associated with CP and PB (Eisenberg et al., 2010; Mullins-Nelson et al., 2006). As a result, it is important to test hypothesized associations above and beyond the effects of age and sex.

METHOD

Participants and procedure

Children participating in the present study were selected from a larger study ($N = 1652$) that collected data from 116 kindergarten and elementary schools in the three largest cities in Cyprus—Nicosia, Larnaca, and Limassol (collected from 2015 to 2016). From this larger sample, 147 Greek-Cypriot children ($M_{age} = 7.30$, SD = 1.42; 44.2% girls) participated in the experimental phase of the study (collected from 2017 to 2018). Three separate random selection procedures were completed to select children at low (<1 SD below the mean, $n = 49$), moderate (−1 SD to +1 SD, $n = 47$), and high (>1 SD, $n = 51$) intensity of CP, as assessed with the Eyberg Child Behavior Inventory (ECBI) that was administered at screening. These groups were not significantly different on levels of PB, $t(145) = 1.71$, $p = .09$, and parental distress, $t(145) = 0.28$, $p = .78$. Due to technical issues, we lost physiological data from eight children, resulting in a final sample of 139 children.

The study procedures received approval from the Cyprus National Bioethics committee. Following approval, research team members informed families about the nature of the study and invited them to participate in the experimental phase of the study. After providing written consent for their child's participation, parents completed an online questionnaire package, using a secure internet-based platform, to assess parental distress, CP, and PB. Reports were received from all mothers and the majority of fathers ($n = 129$). Teachers ($n = 98$) were also invited to complete measures related to children's CP and PB. One year after completing the study, a smaller sample of mothers completed a short questionnaire to investigate potential longitudinal associations ($n = 95$). Attrition was due to the unavailability or mothers or changes in contact information. The age range of parents was from 26 to 58 years, and the majority (70%) of them were between 30 and 40 years of age. Most parents were married (83.2%) and in full-time employment (74%). In addition, 69% of parents completed high school, 29% had a university degree, and only 2% did not complete high school, which is representative of the demographics in Cyprus. All participants were Greek-Cypriots, which is the largest ethnolinguistic community in Cyprus, and had a good knowledge of the Greek language.

Questionnaires

CP and PB

Conduct problem and PB were assessed with the parent and teacher versions of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). SDQ is a 25-item rating scale consisting of five subscales with five items each: Hyperactivity, CP, Emotional Symptoms, Peer Problems, and PB. Mothers, fathers, and teachers rated only the items assessing CP behaviors in the last 6 months (e.g., often fights with other children or bullies them) and PB (e.g., is kind to younger children) using a three-point Likert scale, ranging from 0 “not true” to 2 “certainly true.” Mother and father reports of CP (r = .65, p < .001) and PB (r = .56, p < .001) were significantly correlated and both parent reports were moderately correlated with teacher reports (r = .34–.42, p < .001). Scores were averaged across informants at the item level to create the two measures. In the case of missing data by teachers or fathers, reports from mothers were used. After a year, SDQ PB and CP were re-administered but only to mothers. In the present study, both SDQ CP (α = .73–.75) and PB (α = .70–.72) subscales showed good internal consistency across time. The ECBI (Eyberg, 1999), a 36-item parent-rating scale, was also used to assess children's CP. Mothers and fathers reported their child's behavioral problems using a Likert scale, ranging from 1 "never" to 7 "always." An example item of the ECBI is "The child physically fights with friends his/her own age." Mother and father reports were highly correlated and were combined at the item level (r = .63, p < .001). The ECBI CP scores showed good internal consistency (α = .82).

Parental distress

The Parenting Stress Index-Short Form (Abidin & Brunner, 1995) measures parenting-related distress. For the current study, we only administered the 12-item parental distress subscale (i.e., "I feel that I cannot handle things"; "I gave up my life, for my children's needs"), and we excluded the 24 items assessing the Parent–Child Dysfunctional Interaction and the Difficult Child subscales. Parental distress mainly relates to stress due to the demands associated with having a child and restrictions placed on other life roles. Mothers and fathers rated each item on a Likert scale ranging from 1 "strongly disagree" to 5 "strongly agree." Mother and father reports were significantly correlated and were combined at the item level (r = .44, p < .001). In the present study, the parental distress subscale showed good internal consistency (α = .87).

Experimental procedure and physiological measures

Experimental procedure

Initially, mothers and children were welcomed to the laboratory, and the researcher discussed the study's procedures with them. To minimize distress, we allowed some time for children to familiarize themselves with the room, and the researcher asked them to draw a picture to add to our laboratory wall. Next, the researcher asked the child to sit in a comfortable chair and made all necessary adjustments so that the child could see the computer screen at eye level. After this step, children were fitted with physiological sensors and then performed a series of tests to ensure that HR and SC activity was in the normal range. At the beginning of the experimental session, children viewed a blank computer screen, while their baseline physiological activity was recorded for 60 s. After this first step, children watched 10 fearful (e.g., a snake ready to attack) and 10 neutral (e.g., spoon) pictures, presented randomly for 5 s each. We instructed children to minimize their movements and passively view the pictures. The selected pictures were acquired from the well-validated International Affective Picture System (IAPS; Lang et al., 1997). Before each picture was displayed, children saw an asterisk at the center of the screen. Inter-trial intervals varied from 3.5 to 10.5 s. The experimental procedure (e.g., preparation, stimuli presentation, and sensor removal) lasted approximately 20 min. At the end of the experiment session, children and their mothers were debriefed.

Apparatus

To set up the task (e.g., controlling the timing and presentation of the fearful and neutral pictures), we used an E-Prime 2.0 script (Schneider et al., 2002). Stimuli were presented on a 22-in. (maximum resolution of 1680 × 1050 pixels) computer screen, and children were placed approximately 60 cm from the screen. SC and HR signals were collected using BIOPAC MP150 for Windows bio-amplifiers and transducers, and we used the Acq 4.3 software for data acquisition and processing (Biopac Systems Inc.). During the experiment, we monitored all physiological signals.

Physiological data

After the 60s baseline period, pictures were presented and physiological activity was collected. HR and SC data were acquired using the electrocardiography (ECG) and galvanic skin response modules, respectively, of the BIOPAC system. We used two sets of 11-mm disposable Ag/AgCl pre-gelled electrodes for all physiological recordings. To measure HR, we placed the electrodes on the participant's left and right inner forearms. To measure SC, electrodes were placed adjacently on the hypothenar eminence of the palmar surface of the non-dominant hand. Children were instructed to keep their hands facing palm-up to reduce hand movement artifacts. ECG signals were amplified with a gain of 500, filtered using a Biopac ECG100C bioamplifier, sampled online at 1000 Hz, and then converted offline to beats per minute values. SC data were acquired in microSiemens (μS), and the SC signal was amplified with a gain of 10 μS/V and sampled online at 250 Hz. During the conversion of HR and SC data, we performed a visual inspection to remove artifacts or recordings that occurred due to technical errors (e.g., detachment of electrodes). Finally, mean levels of HR and SC were calculated by averaging the activity during the presentation of fearful and neutral pictures.

Plan of analysis

Calculation of HR and SC reactivity measures

HR and SC reactivity were computed by subtracting physiological activity during neutral pictures from activity during fearful pictures. The difference between emotional from neutral stimuli is considered an "index" score of physiological reactivity. This method was verified by multiple studies (e.g., Fanti et al., 2017; Miller et al., 2002), which used this procedure because physiological activity during neutral and emotional stimuli is directly comparable. In contrast to the baseline condition, during which participants usually view a blank computer screen, picture stimuli are presented in both emotional and neutral conditions.

Analysis

All the analyses were conducted in SPSS 27. We used correlation analysis to investigate the association between parental distress, CP, and PB with HR and SC reactivity to fear. We then ran hierarchical multiple regression analyses with CP, assessed with the SDQ and ECBI, and PB being the dependent variables. In step 1 of all analyses, we controlled for sex and age and included parental distress, HR, and SC reactivity as predictors. For longitudinal analysis, we also controlled for Time 1 CP or PB. In step 2, we included the two-way interactions between the predictors. All variables used in interactions were standardized (*z*-scores). Interactions were visualized using the open-source interactive data visualization tool (McCabe et al., 2018). Both multiple small plots, which present an individual plot for each level of the moderator, and marginal effect plots, which provide a visualization of the regions of significance, were used to interpret the significant interactions.

RESULTS

Correlational analysis

As shown in Table 1, parental distress was positively correlated with Time 1 and Time 2 CP assessed with the SDQ. Further, parental distress was negatively associated with children's HR reactivity, suggesting that children whose parents experienced distress were less likely to react to fear stimuli. HR reactivity was also negatively associated with Time 2 CP and positively associated with Time 2 PB. The CP variables were positively inter-correlated and negatively associated with PB cross-sectionally and across time.

Hierarchical linear regression analysis

The regression analyses with the CP variables as the outcomes are shown in Table 2, and the regression analysis with PB as the outcome is shown in Table 3.

TABLE 1 Correlational analysis

	1	2	3	4	5	6	7	8	9
1. Parental distress	1								
2. HR reactivity	−.21**	1							
3. SC reactivity	.06	−.09	1						
4. Time 1 CP (SDQ)	.26**	−.13	.09	1					
5. Time 1 prosocial behavior	−.14	.15	−.02	−.39**	1				
6. CP (ECBI)	.10	−.04	.11	.64**	−.45**	1			
7. Time 2 CP (SDQ)	.22*	−.21*	−.05	.78**	−.47**	.53**	1		
8. Time 2 prosocial behavior	−.11	.30**	.14	−.40**	.55**	−.23*	−.49**	1	
Descriptive									
M	24.04	0.61	−0.03	2.39	7.25	19.26	7.50	11.00	1
SD	8.25	4.04	1.77	1.99	1.92	7.17	2.57	7.28	7.28

Note: All measures, except parental distress, refer to children's physiological reactivity and behaviors.

Abbreviations: CP, conduct problem; ECBI, Eyberg Child Behavior Inventory; HR, heart rate; SC, skin conductance; SDQ, Strengths and Difficulties Questionnaire.

*$p < .05$; **$p < .01$.

TABLE 2 Results of hierarchical regression analysis with conduct problems as the outcome

	T1 conduct problems (SDQ)				T2 conduct problems (SDQ)				T1 conduct problems (ECBI)			
Variable	***B***	**SE *B***	***b***	**R^2**	***B***	**SE *B***	***b***	**R^2**	***B***	**SE *B***	***b***	**R^2**
Step 1				.10*				.65**				.06
Time 1 CP					.85	.07	.78**					
Child's age	.01	.01	.13		.04	.01	.01		−.06	.57	−.01	
Child's sex (0 = boys, 1 = girls)	.01	.01	.08		.01	.01	.01		−2.25	1.55	−.16	
Parental distress	.49	.19	.22**		.11	.14	.05		.09	.10	.10	
HR reactivity	−.22	.18	−.11		−.26	.14	−.12		−.02	.19	−.01	
SC reactivity	.16	.19	.07		−.33	.14	−.16*		.44	.41	.12	
Step 2				.18**				.66**				.18**
Time 1 CP					.86	.08	.79**					
Parental distress	.44	.18	.20**		.12	.14	.06		.08	.10	.09	
HR reactivity	−.15	.18	.10		−.28	.15	−.13		.07	.19	.04	
SC reactivity	.21	.18	.10		−.33	.14	−.16*		.51	.39	.13	
HR × parental distress	.01	.16	.01		.07	.12	.03		−.02	.02	−.10	
SC × parental distress	.81	.24	.29**		−.06	.19	.02		.21	.06	.34**	

Abbreviations: CP, conduct problem; ECBI, Eyberg Child Behavior Inventory; HR, heart rate; SC, skin conductance; SDQ, Strengths and Difficulties Questionnaire.
*$p<.05$; **$p<.01$.

TABLE 3 Results of hierarchical regression analysis with prosocial behavior as the outcome

Variable	T1 prosocial behavior				T2 prosocial behavior			
	B	SE *B*	*b*	R^2	*B*	SE *B*	*b*	R^2
Step 1				.05				.34*
T1 prosocial behavior					.18	.04	.44**	
Child's age	.01	.01	.19		.01	.01	.11	
Child's sex (0 = boys, 1 = girls)	−.01	.01	−.21		−.01	.01	−.10	
Parental distress	−.19	.18	−.10		.33	.16	.17	
HR reactivity	.22	.18	.12		.51	.17	.28*	
SC reactivity	−.03	.18	−.02		.19	.16	.10	
Step 2				.14**				.39**
T1 prosocial behavior					.17	.04	.42**	
Parental distress	−.14	.18	−.07		.36	.16	.20	
HR reactivity	.12	.17	.06		.47	.16	.26*	
SC reactivity	−.06	.18	−.03		.16	.16	.09	
HR × parental distress	.16	.15	.09		.01	.14	.01	
SC × parental distress	−.74	.22	−.28**		−.54	.20	−.24*	

Note: All measures, except parental distress, refer to children's physiological reactivity and behaviors.

Abbreviations: CP, conduct problem; ECBI, Eyberg Child Behavior Inventory; HR, heart rate; SC, skin conductance; SDQ, Strengths and Difficulties Questionnaire.

*$p<.05$; **$p<.01$.

Cross-sectional associations with CP

Time 1 CP (SDQ)

Findings from step 1 revealed that only parental distress was positively associated with children's CP. The analysis also showed a significant two-way interaction between parental distress and the child's SC reactivity to fear (see step 2). Post hoc probing of the interaction effect was used to determine whether the association between parental distress and CP was significant at high, average, or low levels of SC reactivity. The findings suggested opposite associations between parental distress and the child's CP at low (−2 SD) and average or high levels of SC reactivity (Figure 1a). The positive association between parental distress and CP increased in strength when SC reactivity was higher. As shown in the marginal effects plot (Figure 1b), the simple slope of parental distress on CP was significant and negative when SC reactivity was −1.65 SD away from the mean or greater, with 5% of participants being within this region. The simple slope of parental distress on CP was significant and positive when SC reactivity was −0.05 SD away from the mean or greater, with 63% of participants falling within this region. Therefore, the combination of high parental distress and high child SC reactivity resulted in increased levels of CP in the majority of the sample.

Time 1 CP (ECBI)

No significant main effects from the regression analysis with the ECBI CP as the outcome were identified. Only the interaction between parental distress and SC reactivity was significant. Similar to prior analysis, findings suggested that parental distress was associated with increases in CP among children high on SC reactivity, and was negatively associated with CP for those low on SC reactivity (Figure 2a). Both the positive and negative associations between parental distress and CP increased in strength with increases or decreases in SC reactivity, respectively. Parental distress was not associated with CP at average levels of SC reactivity. The marginal effects plot (Figure 2b) shows that the simple slope of parental distress on CP was significant and negative when SC reactivity was −0.75 SDs away from the mean or further, including 11.51% of observations within this region. The simple slope of parental distress on CP was significant and positive when SC reactivity was 0.40 SDs away from the mean or further, which included 22.3% of observations.

Longitudinal associations with CP

Time 2 CP (SDQ)

Findings from step 1 revealed that Time 1 CP strongly predicted Time 2 CP. In addition, SC reactivity was negatively associated with Time 2 CP even after accounting for continuity in CP. This finding suggests that low reactive or fearless children were more likely to engage in CP. No significant interactions were identified in step 2.

Cross-sectional associations with PB

Time 1 PB

As shown in Table 3, only the interaction between parental distress and SC significantly predicted PB. Findings

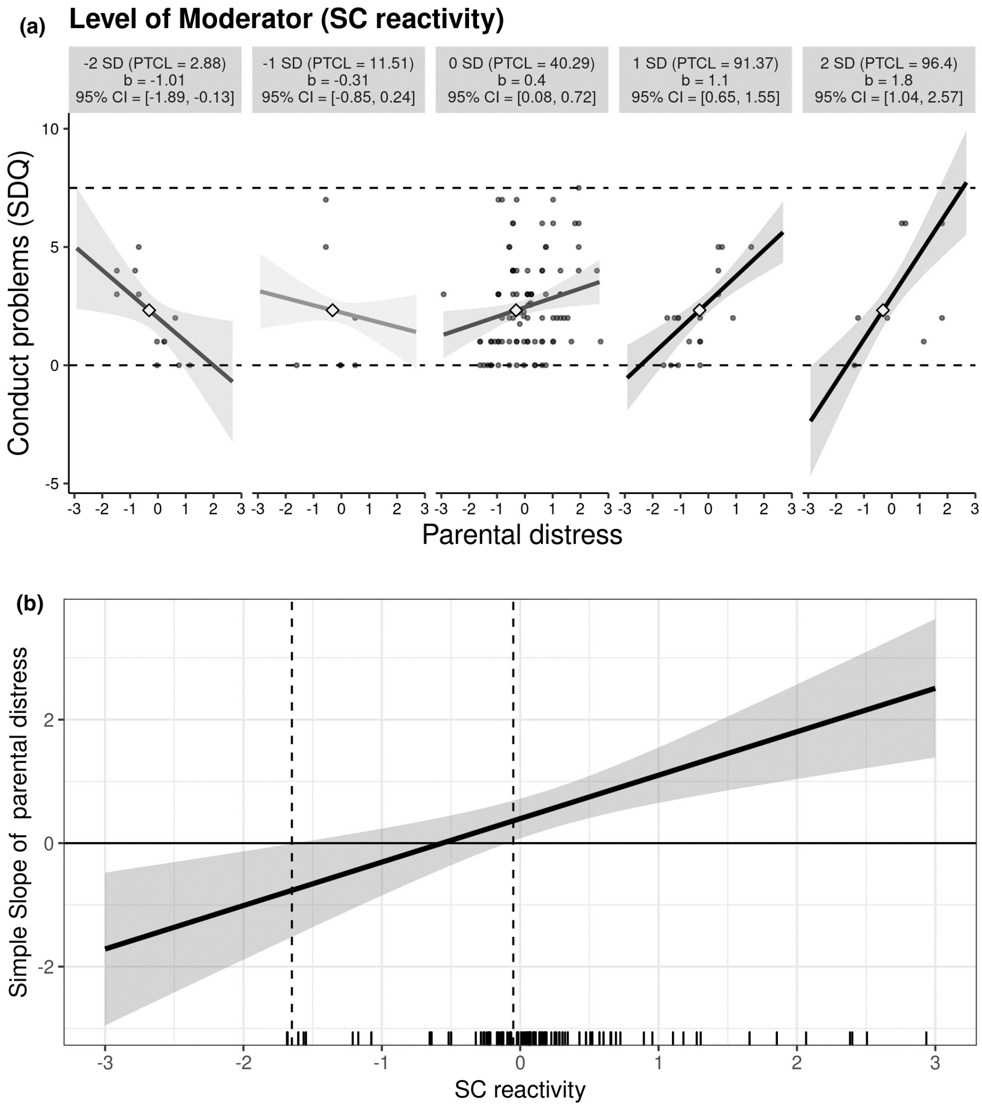

FIGURE 1 (a) Small multiple plot of the interaction between parental distress with child's skin conductance (SC) reactivity predicting Time 1 conduct problems assessed with the Strengths and Difficulties Questionnaire (SDQ). *b*, simple slope; CI, confidence interval; PTCL, percentile; SD, standard deviation. (b) Marginal effect plot of the interaction between parental distress with child's SC reactivity predicting Time 1 conduct problems assessed with the SDQ

suggested that parental distress was associated with decreases in PB among children high in SC reactivity, but increases in PB for children low in SC reactivity, with no significant association at average levels of SC reactivity (see Figure 3a). Both positive and negative associations between parental distress and PB increased in strength with increases or decreases in SC reactivity, respectively. The simple slope of parental distress on PB was significant and negative when SC reactivity was 0.25 SD away from the mean, including 28.78% of observations within this region (Figure 3b). The simple slope of parental distress on PB was significant and positive when SC reactivity was −0.90 SDs away from the mean, with 11.51% of observations in this region. These findings suggest that high and low SC reactivity to fear stimuli influence children's PB in the context of parental distress, pointing to opposite effects among different levels of fear reactivity.

Longitudinal associations with PB

Time 2 PB

Findings from step 1 suggested that HR reactivity was positively related to Time 2 PB even after controlling for continuity in PB (Table 3). Similar to cross-sectional findings, the interaction between parental distress and SC significantly predicted Time 2 PB above and beyond initial levels of PB. Findings suggested that parental distress was associated with increases in PB among children low on SC reactivity (−1 and −2 SD) and decreases in PB for those high in SC reactivity (2 SD; Figure 4a). The simple slope of parental distress on Time 2 PB was significant and negative when SC reactivity was 1.5 SDs away from the mean, with 6.3% of observations within this region (Figure 4b). The simple slope of parental distress on PB was significant and positive when SC reactivity was

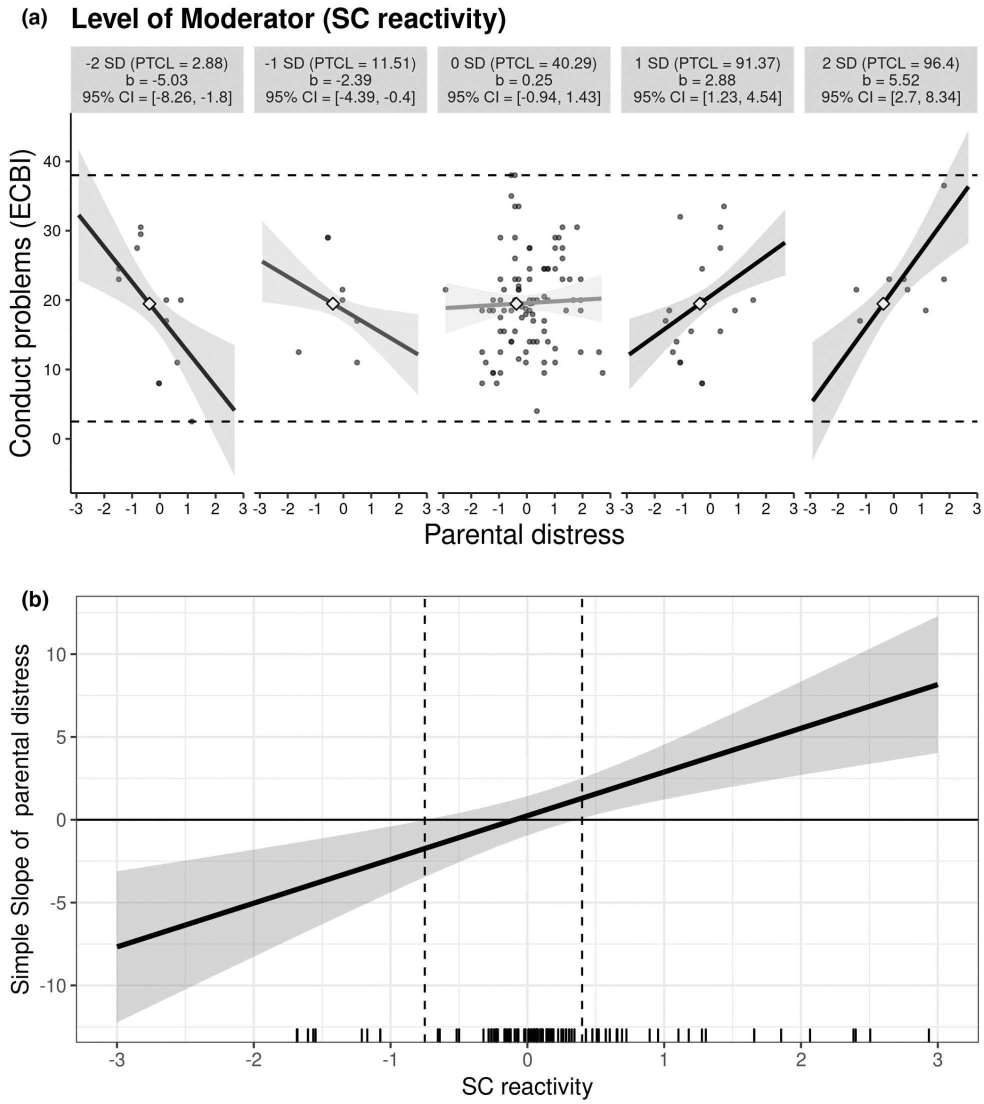

FIGURE 2 (a) Small multiple plot of the interaction between parental distress with child's skin conductance (SC) reactivity predicting Time 1 conduct problems assessed with the Eyberg Child Behavior Inventory (ECBI). *b*, simple slope; CI, confidence interval; PTCL, percentile; SD, standard deviation. (b) Marginal effect plot of the interaction between parental distress with child's SC reactivity predicting Time 1 conduct problems assessed with the ECBI

−0.15 SD away from the mean or further, with 31.6% of observations within this region.

DISCUSSION

The current study examined the unique and interactive effects of parental distress and children's physiological reactions (HR and SC reactivity) to fearful pictures in predicting CP and PB cross-sectionally and longitudinally. Direct associations suggested that children whose parents experienced parental distress (i.e., reported less satisfaction with their parenting role and/or performance) presented higher CP. Distressed parents might not be able to teach their children how to regulate their behaviors or emotions or how to cope with stressful experiences during a critical developmental stage resulting in increased antisocial behaviors (Mathis & Bierman, 2015). Additionally, an important risk factor for presenting elevated CP across time was the child's low SC reactivity, even after accounting for initial levels of CP. In contrast, it was high HR reactivity to fear that was associated with developmental change in PB, suggesting that elevated HR reactivity acted as a protective factor. Importantly, SC reactivity to fearful stimuli moderated the association between parenting distress with both CP and PB. Compared to children low on SC reactivity, those with above average levels of SC reactivity to fear were more susceptible to the effects of parental distress, as indicated by their higher vulnerability to engage in CP behaviors, which was only significant cross-sectionally, and their lower scores on initial and future levels of PB. No effects of gender and age were identified.

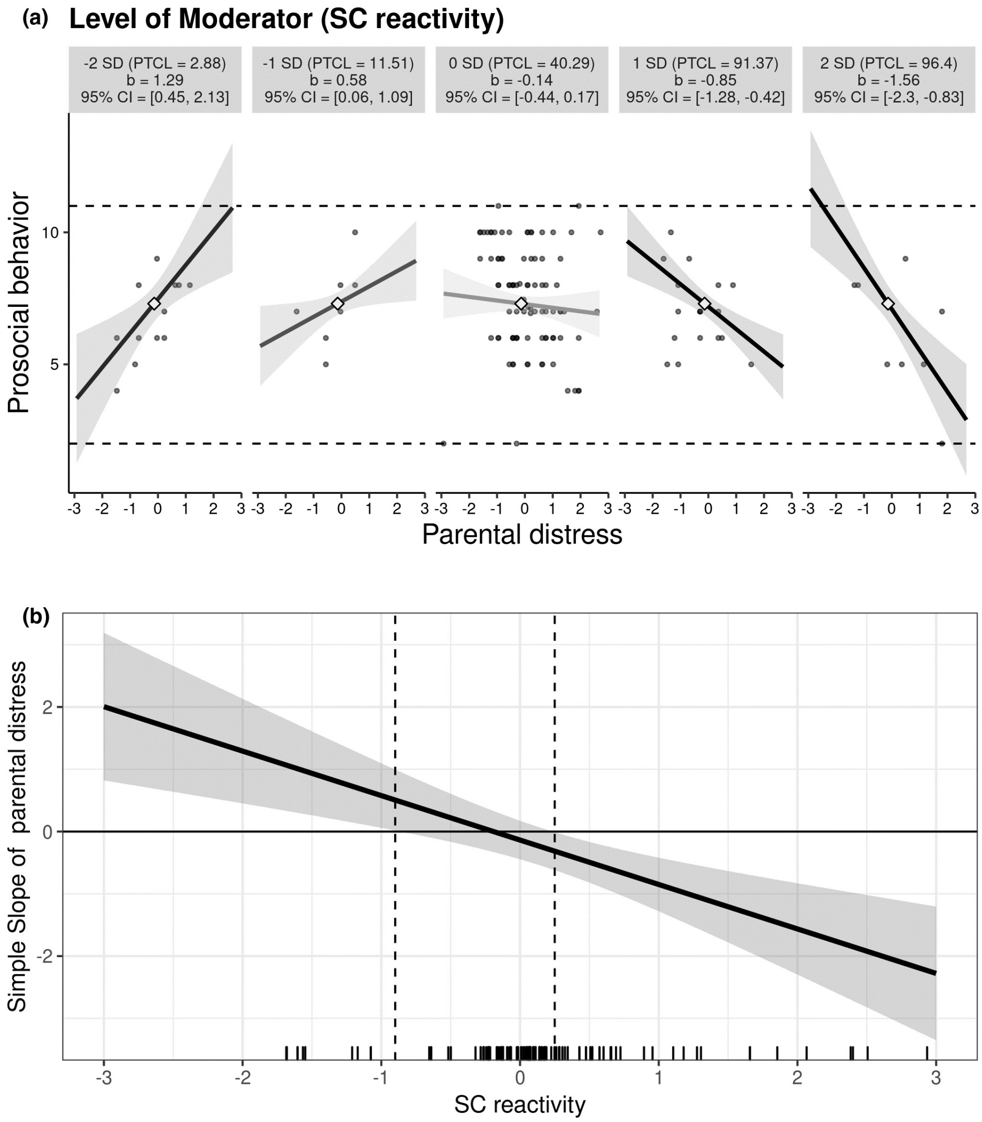

FIGURE 3 (a) Small multiple plot of the interaction between parental distress with child's skin conductance (SC) reactivity predicting Time 1 prosocial behavior. *b*, simple slope; CI, confidence interval; PTCL, percentile; SD, standard deviation. (b) Marginal effect plot of the interaction between parental distress with child's SC reactivity predicting Time 1 prosocial behavior

CPs and physiological reactivity

Similar to prior work, parental distress predicted CP, when initially assessed with the SDQ at Time 1 (Amrock & Weitzman, 2014; Fanti & Munoz Centifanti, 2014). Importantly, our results indicated that the child's SC reactivity was positively associated with elevated CP behaviors only in the presence of parental distress during the initial assessment. This study's findings show that physiological reactivity may have a moderating role in the association between environmental measures with CP. Specifically, higher parental distress was positively associated with increased levels of CP, assessed cross-sectionally with the SDQ and ECBI measures, only among children with heightened (above average) SC reactivity to fear. However, only one prior study investigated the interaction between SC reactivity and parental distress, showing that parental distress increased the risk of CP among children with low SC reactivity to emotional stimuli (Buodo et al., 2013). In contrast to our work that focused on fear stimuli, Buodo et al. (2013) created two clusters of participants with low or high SC reactivity to emotional stimuli that included pleasant and unpleasant pictures. As a result, it might be that high SC reactivity specifically to fear stimuli, which is associated with higher threat sensitivity, may amplify the effects of parental distress on CP behaviors.

Current evidence agrees with several studies finding that greater SC reactivity to stressful experiences can explain associations between familial risk factors and CP. Indeed, high SC reactivity has been shown to operate as a moderator in the context of diverse familial risk factors, including parental depressive symptoms (Cummings et al., 2007), harsh parenting (Bubier

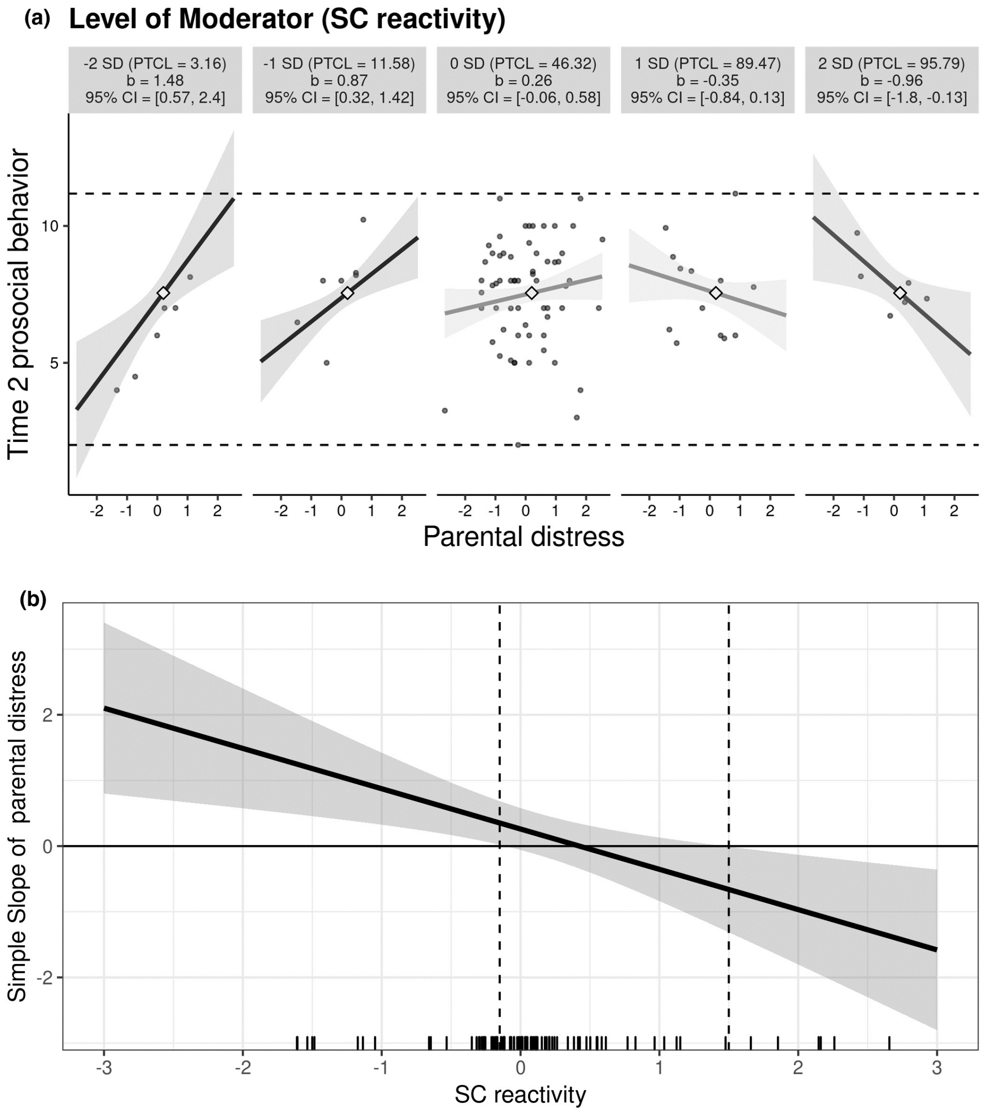

FIGURE 4 (a) Small multiple plot of the interaction between parental distress with child's skin conductance (SC) reactivity predicting Time 2 prosocial behavior. *b*, simple slope; CI, confidence interval; PTCL, percentile; SD, standard deviation. (b) Marginal effect plot of the interaction between parental distress with child's SC reactivity predicting Time 2 prosocial behavior

et al., 2009), and marital conflict (El-Sheikh, 2005; El-Sheikh et al., 2007; Philbrook et al., 2018). Children high on SC reactivity might be more vulnerable or susceptible to the influences of negative familial experiences and parental distress due to their increased biological sensitivity to contextual experiences, poor emotion regulation, and poor coping, which eventually lead to CP (Erath et al., 2011). These findings agree with the biological sensitivity to context theory, which postulates that individuals with high, but not low, physiological reactivity might be more attuned or show enhanced sensitivity to social experiences (Belsky & Pluess, 2009; Boyce & Ellis, 2005).

On the other hand, our findings suggested that children low on SC reactivity might be unresponsive or not affected by parental distress, as suggested by the negative association between parental distress and CP at low levels of SC reactivity to fear. Thus, low physiological sensitivity to emotional stimuli might protect children from the adverse effects of parental distress. Agreeing with this suggestion, Bubier et al. (2009) found that harsh parenting was associated with increased externalizing problems among children with high physiological reactivity but decreases in externalizing problems among those with low reactivity. These findings highlight the importance of SC reactivity as a mechanism that can either exacerbate or minimize the effects of negative parental experiences.

This interactive association changed once we accounted for CP reports from Time 1 in the regression model, with findings suggesting that low SC reactivity irrespective of parental distress was a significant predictor for CP across time. This finding is in accordance with prior evidence that low physiological reactivity to fear is a primary predictor of such behaviors (Lorber, 2004; Raine, 2002). As a result, although low SC reactivity might be a coping mechanism for the negative effects of parental distress on children's behavior cross-sectionally, the fearlessness and insensitivity to punishment characterizing these children might be detrimental for their development, in the long run, increasing CP behaviors. Interestingly, this was the case for SC reactivity but not for HR when examining CP. In a recent meta-analysis, Fanti et al. (2019) provided evidence for inconsistencies regarding the association between physiological responses and CP, and our findings point to SC reactivity as a more important predictor and moderator of CP behaviors.

PB and physiological reactivity

Parental distress was not directly related to PB, with findings pointing to interaction effects between parental distress with children's physiological reactivity both cross-sectionally and longitudinally. The identified associations suggested unique and even opposite influences of HR and SC systems. These results agree with prior findings that both SC and HR reactivity to laboratory stressors explain the link between negative familial experiences and behavioral adjustment (Philbrook et al., 2018). Regarding SC, parental distress was linked to decreased PB among children with high SC reactivity during exposure to fear stimuli, but high PB among children with low SC reactivity to fear. This finding is consistent with suggestions that negative parenting is associated with higher sensation-seeking or impulsive behaviors, resulting in low PB (Belsky & Pluess, 2009; Boyce & Ellis, 2005). Our findings also agree with the biological sensitivity to context theory. According to this theoretical framework, due to their greater susceptibility to contextual experiences, highly reactive children might be more likely to negatively respond to adverse environments (Sijtsema et al., 2013), resulting in lower PB or increased CP. On the other hand, parental distress was positively associated with PB among children low on SC reactivity. Thus, our findings suggested that children showing lower SC reactivity to fear stimuli may present a coping mechanism and actually benefit from parental distress, resulting in enhanced PB. Therefore, SC reactivity can act as a protective or a susceptibility factor in response to parental distress. Although these findings need to be replicated by future work, our results suggest that SC reactivity can either increase or decrease the effects of negative familial experiences.

After accounting for initial levels of PB, HR reactivity directly predicted longitudinal change in PB, suggesting that elevated HR reactivity to fearful stimuli might be a protective factor enhancing prosocial development. This finding is aligned with prior work suggesting that heightened reactivity operates as a protective factor as it was associated with lower antisocial behavior and more prosociality (Sijtsema et al., 2013). Agreeing with this suggestion, Von Dawans et al. (2012) actually showed that experiences of stress during a laboratory task were more likely to result in prosocial (e.g., trust and sharing) than antisocial responses. These researchers suggest that high-stress reactivity does not necessarily lead to negative behavioral outcomes. In fact, as our study suggests, children high on HR reactivity might be more attentive to environmental changes associated with fear, leading to PB. According to Von Dawans et al. (2012), stress may enhance social approach behavior, which operates as a stress-buffering strategy and leads to PBs.

Thus, current findings suggest that more prosociality is associated with higher HR reactivity and lower SC reactivity in the context of parental distress, and as such physiological functioning could also be seen as a protective factor that might enhance PB. However, it remains unclear why the association with HR was specific to PB and not CP, as our findings suggest. Future studies should further investigate such differences in HR and SC reactivity. Identifying HR and SC reactivity as biomarkers for CP and PB in children could pave the way toward a better understanding of individual protective factors that might enhance children's developmental adjustment.

Finally, current findings suggest that children who are more reactive physiologically to aversive and fearful experiences might be less likely to cope with parental distress, which exacerbates their behavioral problems and decreases levels of PB. It is also possible that exposure to parental distress, associated with high levels of negative emotional arousal, might provide a model for emotional responding adopted by the child, who might progress to emotional dysregulation and interpersonal difficulties (Raine et al., 2014). This suggestion agrees with prior evidence that negative parenting during early childhood is associated with greater stress reactivity in children (Gao et al., 2017; Raine et al., 2014). In addition, based on our findings and prior physiological studies (de Wied et al., 2010), it can be concluded that SC reactivity might be a more sensitive physiological marker for CP in the context of negative parenting compared to HR reactivity, even though both measures inform stress reactivity to emotional stimuli. Agreeing with our results, Bubier et al. (2009) suggested that SC but not HR reactivity moderates the association between contextual factors and CP behaviors. Thus, high SC reactivity associated with high sensitivity to fearful experiences might be a specific vulnerability factor that exacerbates the effects of parental distress. In contrast, children exhibiting low SC reactivity to fearful stimuli were at lower risk to engage in CP behaviors and more likely to exhibit PB even after experiencing parenting distress, pointing to both protective and risk functions of SC reactivity.

Limitations, strengths, future directions, and conclusions

The current study's findings should be interpreted in light of some limitations. We investigated children's emotional reactivity by using physiological measurements in a community sample of children, and future studies should replicate these findings in clinical samples. Moreover, despite using static affective stimuli (pictures) that have been validated and used in numerous studies with children, future research may benefit from incorporating movie scenes or imagery scenarios aiming to evoke emotional responses as done in previous work (Fanti et al., 2017; Kyranides et al., 2016). Finally, regarding physiological measures, SC is a marker of sympathetic, while HR reactivity is a marker of both sympathetic and parasympathetic functioning. Adding a pure marker of parasympathetic functioning (e.g., respiratory sinus arrhythmia) could lead to clearer conclusions. To account for this limitation, we controlled for the covariance between HR and SC reactivity in regression analysis.

The present study also has several notable strengths. First, a multimethod, multi-informant assessment approach was adopted, combining physiological (HR, SC) with behavioral measurements obtained from parents and teachers. Second, both cross-sectional and longitudinal data were collected. Third, CP were assessed using two different well-validated measures (SDQ and ECBI), which resulted in similar interactions between parental distress and child's SC reactivity; thus, enhancing the reliability of our conclusions. Fourth, a large community sample was used during the screening phase for the identification of children that participated in the experimental phase of the study. Finally, the present study is among the first studies investigating the unique and interactive effects of parental distress and children's HR and SC reactivity to fear on the development of CP and PB during childhood. As such, the current study expands the growing literature examining autonomic reactivity as a moderator between familial environment and child behaviors. Findings on PB are of great importance since the majority of prior work focused on antisocial behavior.

In conclusion, current findings demonstrate that measures of physiological reactivity (SC and HR) reflect sensitivity to environmental experiences and can help identify the underlying individual factors associated with impaired emotional processing among children differentiated on CP and PB (Fanti et al., 2018). Our results are in line with several studies suggesting a greater risk for CP among children with above-average levels of SC reactivity experiencing negative interactions with their parents, highlighting the predictive role of neurophysiological markers in the diagnosis of CP (El-Sheikh, 2005; Raine, 2002; Raine et al., 2014). In addition, findings indicate that HR and SC reactivity might function differently since SC was associated with both CP and PB, while HR was mainly associated with PB. As a result, future research should incorporate both SC and HR measures to understand CP and PB, which might also clarify previous inconsistencies regarding the relation between physiological activity and behavioral outcomes. Thus, it is imperative to move beyond the single biomarker approach to better understand the impact of autonomic reactivity on prosocial and antisocial behaviors. Moreover, in accordance with our findings, not all children exposed to parental distress engage in CP, pointing to variability in this association and the importance of accounting for individual differences in physiological reactivity to understand risk and protective processes.

Our findings underline the critical importance of integrating neurophysiological markers of the functionality of the autonomic nervous system during threat conditions (e.g., HR and SC reactivity). Combining physiological reactivity with social-context measures can help conceptualize how CP and PB develop in children and provide further evidence that different levels of parental distress may have distinct etiology in children with specific physiological reactivity. Findings can also inform the design of novel biologically based interventions, such as Biofeedback training, that aim to modify undesirable physiological states and improve physiological arousal in children with CP or low PB (Whitaker & Bushman, 2012). Finally, our findings suggest that parenting interventions should consider children's physiological arousal to fear since these measures can inform how familial experiences influence children's adaptive and maladaptive functioning.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data necessary to reproduce the analyses presented here are not publicly accessible.

ANALYTIC CODE

The analytic code necessary to reproduce the analyses presented in this paper is not publicly accessible.

MATERIALS

The materials necessary to attempt to replicate the findings presented here are publicly accessible (see the International Affective Picture System).

PREREGISTRATION

The analyses presented here were not preregistered.

ETHICS STATEMENT

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and national research committees (Centre of Educational Research and Assessment of Cyprus, Pedagogical Institute, Ministry of Education and Culture, and Cyprus National Bioethics Committee) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

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