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Mother–child adrenocortical synchrony: Roles of maternal overcontrol and child developmental phase

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Abstract

An increasing amount of empirical attention is focused on adrenocortical synchrony as an index of biobehavioral co-regulation between parent and child in the context of early child development. Working with an ethnically diverse community sample of children (N = 99, 50.5% male, ages 9–12), we collected saliva samples from mother–child dyads prior to and after a laboratory-based performance challenge task, and tested whether maternal overcontrol and child age moderated dyadic synchrony in cortisol. Results revealed that cortisol levels between mothers and children were significantly positively correlated at pretask for dyads with mean age and older children only, at 25-min post-task for all dyads, and at 45-min post-task for all dyads. Higher overcontrol/older child dyads exhibited a unique pattern of cortisol synchrony wherein at pretask, mother–child levels had the strongest *positive* correlation, whereas at 25 and 45 min, mother–child cortisol levels were significantly *inversely* correlated. These findings contribute to theory and research on parent–child relationships by examining parenting behavior, developmental stage, and adrenocortical synchrony in tandem.

KEYWORDS
cortisol, middle childhood, overcontrol, parent–child, synchrony

1 | INTRODUCTION

Although initially discussed as a feature specific to parent–infant relationships, we now understand that emotional, cognitive, behavioral, and physiological interdependence of attachment partners traverses developmental stages (Hazan, Gur-Yaish, & Campa, 2004; Sbarra & Hazan, 2008). In particular, physiological co-regulation, in which people's levels of physiological arousal are interdependent (Sbarra & Hazan, 2008), has been studied in romantic partner and parent–child dyads as a relational process that is associated with, and potentially indicative of, relationship quality. Physiological interdependence may be influenced by subconscious processes, much like the matching of linguistic style or facial expressions (Bigelow & Walden, 2009; Ireland et al., 2011; Legerstee & Varghese, 2001). Furthermore, research suggests that close relationship partners play a central role in regulation of arousal. For example, when adult couples complete laboratory tasks, their peripheral physiology is positively associated (Helm, Sbarra, & Ferrer, 2012; Levenson & Gottman, 1983), whereas separation from or loss of a romantic partner disrupts individuals' physiological rhythms (Hofer, 1984; Sbarra & Hazan, 2008), suggesting that the sudden absence of one's co-regulator requires a recalibration of physiological arousal states.

The degree of physiological synchrony, or the extent to which two people's physiology covary, is one way of assessing physiological co-regulation. Here, we assess adrenocortical synchrony between mothers and their children in the period of middle childhood, an understudied developmental phase (Kerns, 2008). As in other studies that assess physiological synchrony, adrenocortical synchrony is measured as the degree to which dyads' physiological arousal correlates, with stronger (positive or negative) correlations assumed to signify greater synchrony. Although physiological synchrony has been assessed in both parent–child and adult–adult dyads, its meaning may differ dramatically due to the differences in the caregiving/regulatory roles served by these two types of relationships. Romantic partnerships are symmetrical in that each person provides and receives care to an approximately equal degree, but parent–child relationships are asymmetrical as the parent typically provides care to the child. Therefore, links between adrenocortical synchrony and relationship quality may differ across parent–child and romantic dyads.

The patterns of association between adrenocortical synchrony and relationship quality in parent–child relationships may also differ based on the age of the child. Between infancy/toddlerhood and middle childhood in particular, children gradually acquire skills to regulate arousal independently: Older children rely more on their own decision-making and regulatory capacities, as well as on judgment and input from peers, to guide their behavior (Gifford-Smith & Brownell, 2003), and parents increasingly remove themselves from the co-regulatory process (Cole, Michel, & Teti, 1994; Sroufe, 1996). Times of stress could be an exception during which responsive parents stand at the ready, mobilized to provide support when their children need it; the increased need for co-regulation in such circumstances may manifest itself in greater synchrony of arousal. In the present study, we examine adrenocortical synchrony in mother–child dyads during low and high stress conditions, and as a function of the degree to which mothers' exhibit parenting behaviors that could thwart developmental needs for increasing independence during middle childhood.

1.1 | Adrenocortical attunement as a measure of physiological synchrony

Cortisol, the primary end product of hypothalamic-pituitary-adrenal (HPA) axis activation, varies diurnally, peaking in the morning hours and dipping in mid-afternoon (Pollard, 1995). Synchrony of cortisol levels within dyads has been described as adrenocortical attunement,[1] or the extent to which two members' cortisol levels are positively correlated and increase or decrease in tandem (Saxbe & Repetti, 2010). Researchers interpret adrenocortical synchrony to suggest that dyads' HPA axes are activated to similar degrees, potentially reflecting similar levels of physiological arousal (Saxbe & Repetti, 2010). The degree of adrenocortical attunement could further signify the degree to which the members of the dyad are influenced by one another's arousal states. Optimally, one partner helps to downregulate the other's aversive arousal and upregulate their appetitive arousal (Sbarra & Hazan, 2008). Ample work suggests that dyads tend to show adrenocortical attunement; in general, both parent–child dyads (Hibel, Granger, Blair, & Finegood, 2015; LeMoult, Chen, Foland-Ross, Burley, & Gotlib, 2015; Papp, Pendry, & Adam, 2009; Williams et al., 2013; Young, Vazquez, Jiang, & Pfeffer, 2006) and couples (Liu, Rovine, Cousino Klein, & Almeida, 2013) show positive synchrony of cortisol.

However, researchers have argued that the degree of adrenocortical synchrony is associated with relationship quality; importantly, the nature of this association between synchrony and relationship quality likely varies as a function of contextual factors, including, but not limited to, the nature of the relationship and the situation in which synchrony is assessed. In the context of adult romantic relationships, evidence generally suggests that as with other forms of physiological synchrony (e.g., synchrony of peripheral physiology), *higher* levels of synchrony (i.e., stronger positive correlations, indicative of less discrepancy in arousal levels at any given moment) are associated with poorer quality relationships among adults (Laws, Sayer, Pietromonaco, & Powers, 2015; Liu et al., 2013; Saxbe et al., 2015; Saxbe & Repetti, 2010) and adolescent couples (Ha et al., 2016; see Timmons, Margolin, & Saxbe, 2015 for a review). Levenson and Gottman (1983) have speculated that higher levels of physiological synchrony among couples when under stress (such as during a conflict) may reflect contagion of arousal states, or an inability to disentangle from a partner's stressful experience, as opposed to a more co-regulatory response to a partner's arousal.

Similarly, *when cortisol is assessed from diurnal or baseline samples* (see Davis, West, Bilms, Morelen, & Suveg, 2018, for a review; Ouellette et al., 2015), most studies of parent–child dyads report a link between higher mother–child cortisol synchrony and poorer parent–child relationship and parenting quality. In dyads with preschoolers, greater cortisol synchrony is present when mothers have a history of depression (Merwin, Smith, Kushner, Lemay, & Dougherty, 2017), show more negative affect (Papp et al., 2009), or have lower parenting sensitivity (Saxbe et al., 2017), as well as in dyads with children who have more negative emotionality (Merwin et al., 2017). Higher synchrony in the diurnal cortisol slopes of mothers and school-aged children is also associated with lower familial affective responsiveness (Williams et al., 2013) and with lower mother–child reciprocity (Pratt et al., 2017). However, at odd with these findings, one study reported that dyads in which mothers spent more time with their children and engaged in more supervision of their children showed greater synchrony in cortisol (Papp et al., 2009).

In comparison to investigations based on parent–child synchrony in diurnal or basal levels of cortisol, a handful of studies examined cortisol synchrony in dyads when children are exposed to stress. These studies report that *higher cortisol synchrony during stress conditions* is associated with more positive parent–child relationship qualities, with one notable exception. Thus, studies of young children reported that higher maternal sensitivity was linked to higher cortisol synchrony between mothers and toddlers during challenging tasks (16- to 17-month-olds: Atkinson et al., 2013; preschoolers: Ruttle, Serbin, Stack, Schwartzman, & Shirtcliff, 2011). Similarly, mothers exhibiting higher sensitivity toward their infants and toddlers showed greater cortisol synchrony with their children when challenging tasks were posed to the children (walking across a balance beam, meeting a stranger, playing with a robot; Sethre-Hofstad, Stansbury, & Rice, 2002; van Bakel & Riksen-Walraven, 2008). These findings suggest that physiological attunement may be adaptive in contexts where young children may have more difficulty coping independently (but see Hibel, Granger, Blair, & Cox, 2009, for contradictory findings in a sample of infants and toddlers). To date, no study has explored cortisol synchrony among parents and school-aged children during child stress exposure. We aim to fill this gap in the literature.

1.2 | Parental overcontrol

Bowlby's attachment theory (1969) theory focused on two central types of parenting insensitivity thought to confer risk for maladjustment in children—failure to provide a secure base (autonomy support) and failure to provide a safe haven (comfort provision) for the developing infant. Overcontrol (OC)—parenting actions that constrain children's cognitions and emotional arousal states (Bögels & Brechman-Toussaint, 2006; Borelli et al., 2015)—is one form of insensitive parental care that undercuts the parent's ability to serve as a secure base for the child's exploration, resulting in failures to promote children's autonomy (Affrunti & Ginsburg, 2012; Grolnick & Pomerantz, 2009; Grusec & Davidov, 2007). Children parented with higher OC hold stronger perceptions that the world is a frightening place, have less motivation to explore, and express lower confidence in their ability to handle stress and control their behavior (Becker, Ginsburg, Domingues, & Tein, 2010; Bögels & Brechman-Toussaint, 2006; Bögels & van Melick, 2004; Chorpita, Brown, & Barlow, 1998; Deci & Ryan, 1985; Hudson, Comer, & Kendall, 2008; McLeod, Wood, & Weisz, 2007; Rapee, 1997; Wood, McLeod, Sigman, Hwang, & Chu, 2003). Parental OC is also a risk factor for the development of anxiety-related problems in children (Bögels & Brechman-Toussaint, 2006; Chorpita & Barlow, 1998; McLeod et al., 2007; Wood et al., 2003) and is associated with anxiety in parents (Bögels & Brechman-Toussaint, 2006; Whaley, Pinto, & Sigman, 1999; but see Turner, Beidel, Roverson-Nay, & Tervo, 2003). In addition to its links with children's and parents' anxiety, OC confers prospective risk for externalizing problems in children (Arnett, 2000; Herman, Dorbusch, Herron, & Herting, 1997; Rogers, Buchanan, & Winchell, 2003). Given its transdiagnostic significance, the role of OC in predicting children's ability to regulate physiological arousal is important to understand.

The impact of parental OC on children is likely to vary as a function of developmental stage because the desire for autonomy varies with age as does children's ability to independently modulate arousal. During middle childhood, strivings for autonomy increase (Grotevant & Cooper, 1998), along with a reduced desire for, reliance on, and connection with parents (Kerns, 2008). The parent–child relationship transitions from one in which physical proximity is of key importance to what scholars refer to as a supervision partnership (Waters, Kondo-Ikemura, Posada, & Richters, 1991) in which children want their parents to be accessible in times of need, but prefer them to stand back so they can act autonomously at other times (Kerns, Tomich, & Kim, 2006; Koehn & Kerns, 2016). Thus, across middle childhood, children's reactions to unwanted parental involvement may shift, such that the negative impact of OC may be stronger among children at the older end of the developmental phase. Likewise, the degree to which controlling behaviors are insensitive may vary as a function of the child's developmental stage: parents of 12-year-olds who exert similar levels of control as parents of 9-year-olds are likely to be more insensitive to their children's needs.

1.3 | Current investigation

Here, we examined mother–child synchrony in adrenocortical hormone levels assessed at baseline and at two time points following a standardized laboratory stressor experienced by the child and observed by the mother. Our overarching aim was to contribute to the science regarding associations between a stage-salient form of parental insensitivity (i.e., OC), children's developmental stage, and mother–child cortisol synchrony during conditions of low and high experimentally-induced stress.

We exposed children to a performance challenge task (PCT; i.e., a series of impossible puzzles); mothers were instructed not to help their children unless children absolutely needed assistance. Mothers' and children's saliva (later assayed for cortisol) was sampled once before (pretask) and twice after conclusion of the challenge task (25-min post-task [post-task$_{25\text{min}}$] and 45-min post-task [post-task$_{45\text{min}}$]). From videotaped interactions of the PCT, we derived measures of observed maternal OC as well as supportive maternal behavior, and help-seeking child behavior; the latter two variables were used as covariates in analyses in order to isolate the unique effects of OC.

We predicted that dyads would show adrenocortical synchrony at all three time points, shown in significant positive associations between mother and child cortisol levels (Hypothesis One). We further predicted that the degree of synchrony would vary as a function of maternal OC and children's age (Hypothesis Two). Finally, based on the notion that cortisol synchrony may change with stress, we anticipated that the pattern of cortisol synchrony and its links with OC and children's age would differ under conditions of lower stress (pretask, post-task$_{45\text{min}}$) and higher stress (post-task$_{25\text{min}}$).

Specifically, we anticipated that, compared to younger child/lower OC dyads, older child/higher OC dyads would show significantly higher cortisol synchrony under low stress conditions (pretask and post-task$_{45\text{min}}$ saliva samples; Prediction A and Prediction C, respectively) and significantly lower synchrony under high stress conditions (post-task$_{25\text{min}}$ samples; Prediction B. This prediction was based on the notion that when displayed by mothers of older children, high levels of OC constitute a form of insensitive parenting, and therefore, these dyads would show the poorest co-regulation of physiological arousal.

2 | METHODS

2.1 | Participants

The protocol for this investigation, The Anxious Piece of the Puzzle (#05312013JBPS-JW1), was approved by the Pomona College Institutional Review Board prior to the beginning of data collection. A power analysis revealed that in order to adequately power an investigation in which we expected moderate effects sizes ($r = 0.3$), a sample size of 84 would enable us to evaluate our hypotheses at $\alpha = 0.05$ and Power = 0.80. To guard against attrition, we aimed to collect data from 100 children. Importantly, however, this sample size would only allow for sufficient power to detect main effects (i.e., degree of adrenocortical synchrony), not interaction effects.

A community sample of school-aged children ($N = 106$, age range: 9–12 years; $M_{age} = 10.28$, $SD_{age} = 1.11$, 50.5% male) and their mothers ($M_{age} = 39.62$, $SD_{age} = 7.20$) were recruited using online postings and flyers. Inclusion criteria included English proficiency; exclusion criteria included a diagnosis of a developmental disability or severe mental illness (e.g., psychosis). The sample was ethnically diverse (43% non-Hispanic White, 21% African American, 21% Hispanic, 10% Asian, and 5% of another ethnic category or mixed race) and ranged in terms of annual household income (30% less than US $40,000, 16% more than $120,000). Over half (62.5%) of the mothers were married or co-residing with a partner.

2.2 | Procedure

Mothers and children provided informed consent and assent, respectively, immediately upon arriving at the laboratory. Participants completed questionnaires; afterward, children and mothers provided pretask saliva samples (described below), which on average occurred 45 min after their arrival at the laboratory. The dyads then participated in the PCT (children attempted to complete puzzles while mothers watched, seated in a chair behind their child). The PCT was videotaped so that mother and child behavior and vocalizations were recorded; the videotapes were later coded for maternal OC, a key variable in this study, and for two potential confounds, maternal support and children's help-seeking behavior.

2.3 | Measures

2.3.1 | Performance challenge task

The PCT is a standardized laboratory task used in prior investigations (see Borelli, Burkhart, Rasmussen, Smiley, & Hellemann, 2018; Borelli et al., 2015; Sichko, Borelli, Rasmussen, & Smiley, 2016; Smiley et al., 2016). It involves computer presentation of six 3- by 3-tile geometric puzzles adapted from the Block Design task in the Wechsler Intelligence Scale for Children-III (Wechsler, 1991). The screen displays an array of 10 square tiles (which were all red, all white, or split diagonally into red/white halves) that can be moved into an empty puzzle frame in the center of the screen that accommodates nine tiles; in the upper left corner of the computer screen is a reduced-size image of the puzzle children are tasked to create. Unbeknownst to the children, the puzzles are impossible to fully solve because only eight of the nine correct pieces needed to solve the puzzle, along with two extraneous pieces, are available. Puzzles were displayed for 50 s each, after which a cartoon frown face appeared, indicating that the puzzle had not been solved correctly. Next, two progress bars appeared for 10 s, showing the child's progress in comparison to other hypothetical children, who, by the end of the task, had correctly solved five out of the six puzzles. Mothers were seated in a chair six feet behind the child and were asked not to help unless they felt the child really needed it.

2.3.2 | Collection of saliva and determination of salivary cortisol

We assessed mothers' and children's cortisol levels immediately before the PCT (pretask), approximately 25 min following the end of the PCT (post-task$_{25}$; $M_{time} = 43$ min after pretask assessment), and following a 30-min period post-task (post-task$_{45min}$ cortisol; $M_{time} = 33$ min after post-task$_{25}$ cortisol assessment). Most (76%) of the assessments occurred between noon and 5 p.m.; all others occurred between 11 a.m. and noon.

Saliva was collected from mothers and children using absorbent swabs placed in their mouths for 2 min (Sarstedt, Newton, NC). After collection, samples were frozen at −40°C and stored. Frozen samples were transported for assay. Cortisol was assayed in duplicate using a commercially available immunoassay without modification to the manufacturer's recommended protocol (Salimetrics, Carlsbad, CA). The test used 25 µl of saliva, has a range of sensitivity from 0.007 to 3.0 µg/dl, and, on average, inter- and intra-assay coefficients of variation were less than 15 and 5%, respectively. The average of the duplicate assays was used in all statistical analyses. Cortisol values greater than 4.0 µg/dl were recoded to missing, and cortisol values greater than 3 standard deviations ($n = 3$) from the mean were windsorized (1.18, 0.47). We were missing data from 7 dyads due to insufficient saliva; therefore, analyses involved 99 dyads.

2.3.3 | Maternal behavior

We coded mothers' OC from the video-recorded PCT using the Behavioral Involvement Parenting Scale (BIPS; Rasmussen & Borelli, 2015), a scale modeled after the Nursing Child Assessment Satellite Training Teaching Scales (NCAST; Barnard & Eyres, 1979), a common coding system used to assess parent–child interactions. The BIPS was developed as a measure of parental OC and support using definitions of these constructs within the literature and after consulting other coding systems and parenting experts regarding these constructs (Barber, 1996; Bögels & Brechman-Toussaint, 2006; Grusec & Davidov, 2007; Miller, Borelli, & Margolin, 2018). The BIPS was specifically developed to be appropriate for assessing parental OC and support in the context of the PCT, and therefore seeks to capture the full range of parenting behaviors exhibited in this task. OC on the BIPS scale is associated with theoretically-related constructs, such as mothers' and children's autonomic arousal, discrepancies in parent–child perceptions of relationship interdependence, and children's intrinsic motivation (Borelli, Hong, Rasmussen, & Smiley, 2017; Borelli et al., 2017; Borelli, Smiley, Rasmussen, & Gómez, 2016).

A total of 17 behaviors, all of which fall into one of two predetermined categories—OC or support—are coded on the BIPS. For example, any instances in which mothers moved their children's hand over the computer mouse or verbally directed their children to take a certain action were counted as OC, whereas any instances in which mothers praised their children for their effort or patted their children's shoulders were counted as supportive behavior. More specifically, the OC subscale assesses parents' behavioral control during the task, with 9 items tapping verbal (e.g., "Mom uses imperative verbal style more than explanatory when talking about the puzzles") or physical (e.g., "Mom touches child to provide direction on puzzle completion") types of controlling behavior. On the support subscale, there are eight items to assess mothers' verbal (e.g., "Mom makes cheerleading type statements to the child") and physical (e.g., "Mom gently pats, caresses, strokes, hugs, touches, or kisses child during or after puzzle completion") displays of supportive behavior toward her child. One of the eight support subscale items captures the absence of nonsupportive behaviors ("Mom avoids making general negative or uncomplimentary remarks about the child").

Each of the 6-min long segments (50-s puzzle, 10-s feedback, and progress screen) was coded separately for maternal OC and support. On the BIPS, coders rate the presence (score of *1*) or absence (score of *0*) of each of the 17 behaviors during each segment (puzzle) of the PCT. Thus, on any given puzzle, it was possible for mothers to get total BIPS scores ranging from 0 to 17; scores for OC ranged from 0 to 7 on each puzzle and from 0 to 5.5 for support (half points were possible because we averaged two raters' scores for each mother for each puzzle and then computed a total score). For each mother participant, we calculated a total OC and support score across the six puzzles for each subscale. Four coders were trained to rate mother behavior. All PCT sessions were coded by at least two raters. Interrater reliabilities (intraclass correlation coefficients [ICCs]) between rater pairs ranged from 0.84 to 0.99 for the OC subscale, and 0.69 to 0.94 for the support subscale.

On average, in this sample mothers exhibited a total of seven instances of OC ($M = 7.62$, $SD = 7.47$, range = 0–35.5) and 10 instances of supportive behavior ($M = 10.98$, $SD = 3.94$, range = 6–22.5) across the whole PCT (all six puzzles). Most (86% of mothers) were coded by at least one rater as showing some OC and all mothers were coded as showing at least six instances of supportive behavior.

2.4 | Covariates

2.4.1 | Maternal anxiety

Mothers reported on their cognitive, physiological, and emotional symptoms of anxiety using the Beck Anxiety Inventory (Beck, Epstein, Brown, & Steer, 1988), a 21-item self-report questionnaire. Participants indicate the extent to which they were bothered by symptoms during the last week on a four-point scale, ranging from "not at all" (0 points) to "severely" (3 points). The internal consistency, test–retest reliability, and validity of the BAI have been reported (Fydrich, Dowdall, & Chambless, 1992). In this sample, Cronbach's alpha for the total scale was 0.85, which we used as a covariate in analyses.

2.4.2 | Children's help-seeking behavior

We coded children's help-seeking behavior using the Children's Help-seeking Behavior Scale (CHBS; Borelli, Smiley, & Rasmussen, 2016). Coders rate children's direct behavioral requests for help from their mothers during the PCT using three behavioral indicators—turning to look at the mother, asking the mother for help, and saying the mother's name.

In this study, a separate team of six coders rated children's HS behavior on each of the six puzzles. Coders were trained to reliability on 10 cases (ICCs > 0.80); then 2 raters coded each PCT for the remainder of the sample, with ICCs across all rater pairs ranging from 0.81 to 0.95 for HS. We computed mean scores across raters for each child's HS for each puzzle and then computed a mean score across the six puzzles.

On average, in this sample children exhibited two instances of help-seeking ($M = 2.22$, $SD = 2.15$, range = 0–35.5) and mothers produced 11 instances of supportive behavior ($M = 10.98$, $SD = 3.94$, range = 6–12.5) across the whole PCT (all six puzzles). Most children (71%) were coded by at least one rater as showing some help-seeking behavior.

2.5 | Data analytic plan

Researchers use different data analytic methods to assess synchrony depending on the constraints of the data (see Liu, Zhou, Palumbo, Zhou, Palumbo, & Wang, 2016, for a review). To assess cortisol synchrony of mothers and children in this study, we used multilevel modeling (MLM) to analyze cortisol levels nested within dyads. MLM accounts for the interdependence of data by providing unbiased estimates of the standard errors of different regression coefficients (e.g., Hox, 2010).

To conduct MLM analyses, we used restricted maximum likelihood methods of estimation in Stata 15. We specified a two-level model such that maternal cortisol (level 1) was nested within dyads (level 2). To test study hypotheses, we conducted a four-way interaction to model maternal cortisol across collection time points as a function of maternal OC and child age, predicting child cortisol. The results are reported after controlling for the main effects of each predictor (maternal cortisol, maternal OC, child age, and collection time point), as well as the two-way (maternal cortisol × maternal OC, maternal cortisol × child age, maternal cortisol × collection time point, maternal OC × child age, maternal OC × cortisol time point, and child age × collection time point) and three-way (maternal cortisol × maternal OC × child age, maternal cortisol × maternal OC × collection time point, maternal OC × child age × collection time point) interactions.

3 | RESULTS

On average, children's cortisol decreased from pre- to post-task$_{25\text{min}}$, $t(98) = 2.63$, $p = 0.01$, and did not change from post-task$_{25\text{min}}$ to

TABLE 1 Zero-order correlations among key study variables

	M/%	*SD*	2	3	4	5	6	7	8	9	10	11	12	13
1. C age	10.28	1.08	−0.06	0.34**	0.18	0.11	0.22*	−0.01	0.10	0.02	−0.29**	−0.08	0.02	0.01
2. Female	47%	—	—	−0.07	0.19	−0.03	0.16	−0.09	−0.03	0.08	−0.06	−0.02	−0.13	−0.06
3. Mother age	39.43	7.00		—	−0.04	0.13	0.18	0.04	−0.04	−0.13	−0.29**	−0.02	0.13	−0.13
4. C pre-st cort	0.20	0.27			—	0.63***	0.61***	0.32**	0.18	0.35**	−0.01	−0.10	0.01	0.04
5. C post-st cort	0.15	0.14				—	0.75**	0.34*	0.36**	0.25*	−0.18	−0.14	−0.07	0.01
6. C recovery cort	0.14	0.10					—	0.44**	0.33**	0.31**	−0.14	−0.12	−0.08	−0.06
7. M pretask cort	0.19	0.16						—	0.67**	0.52**	−0.10	−0.06	0.02	−0.07
8. M post-task$_{25}$ cort	0.18	0.13							—	0.66**	−0.09	−0.03	−0.10	0.01
9. M post-task$_{45}$ cort	0.17	0.13								—	−0.09	−0.03	−0.02	−0.17
10. M overcontrol	7.62	7.47									—	0.40**	0.18	0.01
11. M support	10.98	3.92										—	0.44**	−0.12
12. C help-seeking	0.38	0.36											—	−0.15
13. M anxiety	6.14	6.11												—

Note. C: child; M: mother; St: stressor; Cort: cortisol; HS: help-seeking.
[a]Boys = 1, girls = 2. $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

post-task$_{45\text{min}}$, $t(98) = 1.62$, $p = 0.11$. On average, mothers' cortisol did not change significantly from pre- to post-task$_{25\text{min}}$, $t(98) = 0.91$, $p = 0.37$, or from post-task$_{25\text{min}}$ to post-task$_{45\text{min}}$, $t(98) = 0.65$, $p = 0.52$. As expected, however, there were individual differences in stressor-related cortisol reactivity. Following Granger et al. (2012), we interpreted the difference from pre- to post-task$_{25\text{min}}$ as a "change" if that difference was greater than 0.02 μg/dl (twice the lower limit of this assay's sensitivity) and at least a 10% increase over pretask level (twice the industry standard for the intra-assay CV). Using these criteria, 24.4% of the children and 30.1% of the mothers showed a stressor-related cortisol increase. On average, mothers and children who showed cortisol reactions to the stressor task increased by 39.84% and 26.38%, respectively. The findings from other data collected on this sample indicate that both children's and mothers' cardiovascular reactivity increased across the PCT, enhancing our confidence that the PCT constituted a stressor (Borelli et al., 2017).

The results of zero-order correlations revealed that mothers' pretask cortisol was positively associated with children's post-task$_{25\text{min}}$ cortisol and post-task$_{45\text{min}}$ cortisol (see Table 1). Similarly, children's pretask cortisol was positively associated with mothers' post-task$_{25\text{min}}$ and post-task$_{45\text{min}}$ cortisol. Mothers' and children's cortisol levels were positively associated at the post-task$_{25\text{min}}$ and post-task$_{45\text{min}}$ collection points, but not at pretask. Maternal OC was greater among younger mothers and for mothers of younger children. Maternal support was positively associated with maternal OC and with children's help-seeking behavior.

3.1 | Hypothesis testing

3.1.1 | Hypothesis one: synchrony in mother–child cortisol levels

The findings of zero-order correlations revealed that pretask mother–child cortisol levels were marginally associated, $r = 0.19$, $p = 0.05$, whereas mother–child post-task$_{25\text{min}}$ cortisol levels, $r = 0.28$, $p = 0.005$, and post-task$_{45\text{min}}$ cortisol levels, $r = 0.32$, $p = 0.002$, were significantly associated. However, Fisher's *r*-to-*z* transformations revealed that none of these correlation coefficients significantly differed from one another.

3.1.2 | Hypothesis two: synchrony as a function of maternal OC, child age, and time point

In order to examine whether synchrony changed as a function of maternal OC behavior differently for younger and older children across the course of the study, we examined a four-way interaction between maternal cortisol, maternal OC, child age, and collection time point. We found a significant four-way interaction of maternal cortisol, maternal OC, child age, and collection time point, [$b_2 = -0.04$, $SE = 0.02$, 95% confidence interval (CI) (−0.08, −0.003), $z = -2.08$, $p = 0.04$; $b_3 = -0.09$, $SE = 0.02$, 95% CI (−0.13, −0.06), $z = -5.34$,

$p < 0.001$; see Table 2]. We describe the nature of this interaction in the subsections that follow.

3.1.3 | Prediction A: pretask synchrony as a function of maternal OC and child age

Probing of the interaction revealed that pretask maternal cortisol levels predicted child pretask cortisol for *older-* (+1 *SD*) aged children [$dy/dx = 1.09$, $SE = 0.26$, 95% CI (0.59, 1.60), $z = 4.24$, $p < 0.001$], but not for *younger* (−1 *SD*) children [$dy/dx = 0.39$, $SE = 0.24$, 95% CI (−0.08, 0.86), $z = 1.63$, $p = 0.10$]. As maternal cortisol levels increased, so did child cortisol levels for older children, but not for younger children. However, the strength of the association between mothers' and older children's pretask cortisol did not differ as a function of level of OC (all p's > 0.05; see Figure 1).

3.1.4 | Prediction B: post-task (25 min) synchrony as a function of maternal OC and child age

Further probing of the interaction revealed that maternal cortisol predicted *older* children's post-task$_{25\text{min}}$ at low [$dy/dx = 0.76$, $SE = 0.29$, 95% CI (0.19, 1.34), $z = 2.61$, $p = 0.009$], but not mean [$dy/dx = 0.35$, $SE = 0.28$, 95% CI (−0.20, 0.91), $z = 1.24$, $p = 0.21$] or high [$dy/dx = -0.06$, $SE = 0.56$, 95% CI (−1.15, 1.03), $z = -0.11$, $p = 0.92$] levels of maternal OC, such that as maternal post-task$_{25\text{min}}$ cortisol increased so did children's post-task$_{25\text{min}}$ cortisol when mothers

TABLE 2 Results of multilevel modeling analysis examining four-way interaction of mother cortisol, maternal overcontrol, child age, and cortisol collection time point as a predictor of child cortisol

Fixed effects parameters	Coefficient	*SE*	95% CI	*z*	*p*
Intercept	0.09	0.33	(−0.57, 0.74)	0.26	0.80
M cort	−0.39	2.15	(−4.61, 3.82)	−0.18	0.86
M OC	0.0002	0.02	(−0.05, 0.05)	0.01	0.99
C age	−0.002	0.03	(−0.07, 0.06)	−0.07	0.95
Time					
Post-task$_{25\text{min}}$	0.14	0.37	(−0.58, 0.86)	0.39	0.70
Post-task$_{45\text{min}}$	−0.50	0.37	(−1.23, 0.23)	−1.34	0.18
M cort × M OC	−0.28	0.19	(−0.65, 0.10)	−1.44	0.15
M cort × C age	0.09	0.20	(−0.31,0.50)	0.46	0.65
M cort × time					
Post-task$_{25\text{min}}$	0.29	1.68	(−3.00, 3.58)	0.17	0.86
Post-task$_{45\text{min}}$	2.71	1.88	(−0.98, 6.40)	1.44	0.15
M OC × C age	0.0002	0.003	(−0.005, 0.005)	0.09	0.93
M OC × time					
Post-task$_{25\text{min}}$	−0.04	0.03	(−0.10, 0.03)	−1.11	0.27
Post-task$_{45\text{min}}$	−0.08	0.03	(−0.14,−0.02)	−2.76	0.01
C age × time					
Post-task$_{25\text{min}}$	−0.01	0.04	(−0.09, 0.06)	−0.41	0.68
Post-task$_{45\text{min}}$	0.05	0.04	(−0.02, 0.12)	1.36	0.17
M cort × M OC × C age	0.03	0.02	(−0.01, 0.07)	1.50	0.13
M cort × M OC × time					
Post-task$_{25\text{min}}$	0.37	0.19	(−0.01, 0.75)	1.92	0.55
Post-task$_{45\text{min}}$	0.82	0.17	(0.48, 1.16)	4.77	<0.001
M cort × C age × time					
Post-task$_{25\text{min}}$	−0.02	0.17	(−0.34, 0.31)	−0.10	0.92
Post-task$_{45\text{min}}$	−0.29	0.19	(−0.65, 0.09)	−1.47	0.14
M OC × C age × time					
Post-task$_{25\text{min}}$	0.004	0.003	(−0.003, 0.01)	1.13	0.26
Post-task$_{45\text{min}}$	0.01	0.003	(0.003, 0.02)	3.03	0.002
M cort × M OC × C age × time					
Post-task$_{25\text{min}}$	−0.04	0.02	(−0.08, −0.002)	−2.08	0.04
Post-task$_{45\text{min}}$	−0.09	0.02	(−0.13, −0.06)	−5.34	<0.001

Note. C: child; M: mom; Cort: Cortisol; OC: overcontrol.

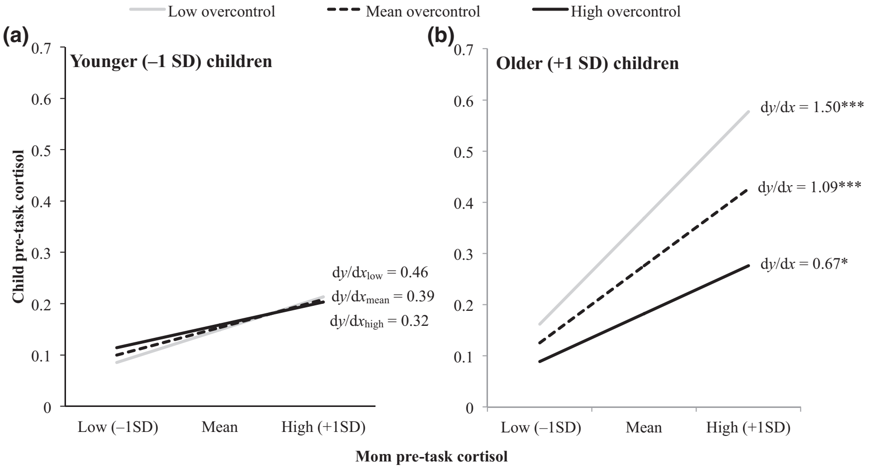

FIGURE 1 Results of multilevel modeling model plotting associations between mom (x-axis) and child (y-axis) pretask cortisol moderated by mom behavioral overcontrol and child age. Interactions graphed at (a) −1 *SD* child age, younger group $M = 9.16$ years, (b) +1 *SD* child age, older group $M = 11.38$ years. Asterisks indicate significant simple slopes, $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

demonstrated low, but not mean or high levels of maternal OC. Maternal post-task$_{25\text{min}}$ cortisol did not significantly predict child post-task$_{25\text{min}}$ cortisol for younger children at low, mean, or high levels of maternal OC (all p's > 0.05; see Figure 2).

3.1.5 | Prediction C: post-task (45 min) synchrony as a function of maternal OC and child age

Further probing of the interaction between maternal cortisol × child age × maternal OC × time point indicated that maternal post-task$_{45\text{min}}$ cortisol predicted *older* aged child post-task$_{45\text{min}}$ cortisol at mean [$dy/dx = -1.27$, $SE = 0.28$, 95% CI (−1.81, −0.73), $z = -4.60$, $p < 0.001$] and high [$dy/dx = -2.73$, $SE = 0.46$, 95% CI (−3.63, −1.82), $z = -5.89$, $p < 0.001$], but not low [$dy/dx = 0.19$, $SE = 0.34$, 95% CI (−0.48, 0.87), $z = 0.56$, $p = 0.58$] levels of maternal OC, such that as maternal post-task$_{45\text{min}}$ cortisol increased, older child post-task$_{45\text{min}}$ cortisol decreased for children of mothers who demonstrated mean and high, but not low levels of maternal OC. Maternal post-task$_{45\text{min}}$ cortisol did not predict child post-task$_{45\text{min}}$ cortisol for *younger* children (all p's > 0.05; see Figure 3).

4 | DISCUSSION

We explored adrenocortical synchrony among mothers and their school-aged children in response to a standardized stressor task as a function of maternal OC and children's age. First, our findings suggested that across the sample as a whole, mothers' and children's cortisol levels were positively associated at post-task$_{25\text{min}}$ and post-task$_{45\text{min}}$, but that they were only marginally associated at pretask. However, we note that in the multilevel model, which accounts for the dyadic interdependence of the data as well as the longitudinal nature of the design, the association between mother and child cortisol levels became less positive from pretask to post-task$_{45\text{min}}$, such that at post-task$_{45\text{min}}$, cortisol levels of mothers and children were negatively associated, among mean-aged and older children. This pattern is partially consistent with Hibel et al. (2015) findings that mother–infant cortisol synchrony was significantly lower following a stressor than it was preceding a stressor, though importantly the pattern we observed was more extreme, as in our study, associations between mother and child cortisol became negative following the stressor.

Consistent with prior research suggesting that higher levels of adrenocortical synchrony during periods of low stress are associated with poorer relationship quality (e.g., Saxbe et al., 2015), we found that only dyads with mean or higher OC demonstrated positive synchrony in pretask cortisol levels, and only dyads with children aged ten or older. Thus, at lower levels of stress (i.e., before the stressor task had begun), greater positive synchrony was associated with more maternal insensitivity during the subsequent stressor task among older children.

As hypothesized, an inverted pattern of effects emerged with respect to cortisol levels obtained post-task—only mothers who exhibited mean or lower levels of OC demonstrated positive cortisol synchrony with their mean-aged or older children during this period. This pattern is consistent with the majority of prior studies conducted with parents and younger children that show an association between greater maternal sensitivity and more positive synchrony when under stress (e.g., Atkinson et al., 2013), but it is inconsistent with the results of one recent study of infants and toddlers. Hibel et al. (2015) found that dyads with lower synchrony under high stress conditions (operationalized as smaller decreases in levels of synchrony in high as compared to low stress contexts) demonstrated signs of better interactional health (Hibel et al., 2015). Their study differed in important ways from the current one (i.e., infants vs. school-aged children; home-based vs. laboratory assessment); an important task for future studies will be to disentangle the potential reasons for the different patterns of effects.

In terms of post-task$_{45\text{min}}$ cortisol, patterns of synchrony were again inverted compared to pretask patterns, with mean-aged or older-children in mean- or higher-OC dyads showing negative associations between mother and child cortisol. Thus, while initially the older child/high OC dyads had the strongest adrenocortical synchrony, at post-task$_{45\text{min}}$, they had the most strongly negative pattern of association in mother–child cortisol levels. That the pattern of synchrony

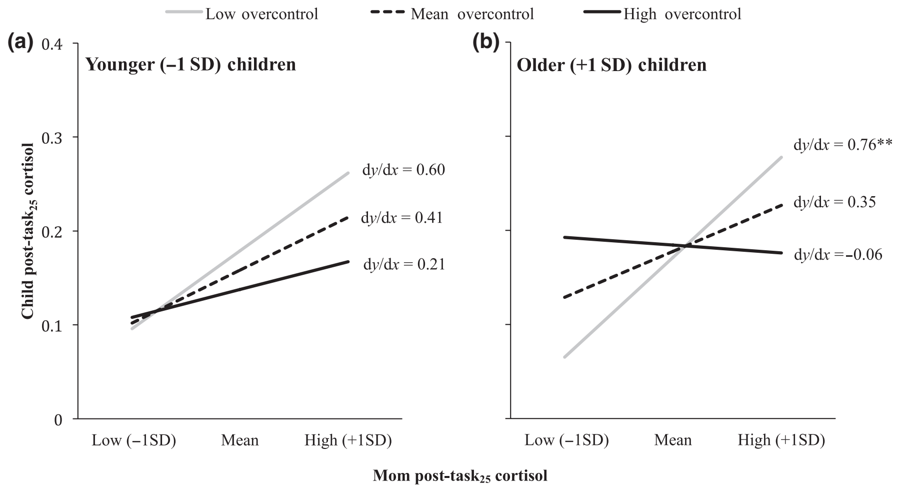

FIGURE 2 Results of multilevel modeling model plotting associations between mom (*x*-axis) and child (*y*-axis) post-task$_{25}$ cortisol moderated by mom behavioral overcontrol and child age. Interactions graphed at (a) −1 *SD* child age, younger group *M* = 9.16 years and (b) +1 *SD* child age, older group *M* = 11.38 years. Asterisks indicate significant simple slopes, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

continued to change in the same direction (decreasing) over the course of sampling causes us to question whether the post-task$_{45\text{min}}$ cortisol actually tapped into a true post-task$_{45\text{min}}$ period (in which case we would have expected patterns of synchrony to return to what was observed at the pretask assessment), or whether it assessed cortisol levels when dyads were still actively coping with the stress caused by the task.

4.1 | Synthesis

Taken together, the effects obtained in this study underscore the importance of three factors in predicting mother–child adrenocortical synchrony—level of stress, mother–child relationship quality (in this case, use of OC), and children's developmental stage. First, with respect to stress level and relationship quality, the associations between positive synchrony and predictor variables changed across the cortisol samplings. At pretask, high OC/older age dyads showed greater positive synchrony; such dyads may be more at risk. However, at both post-task cortisol assessments, these same dyads showed inverse cortisol associations. This pattern of findings is consistent with the results of one study in which high mother anxiety/high mother OC dyads had lower synchrony of cardiovascular arousal (lower arousal in mothers, higher in children; Borelli et al., 2017) when under high stress. While negative relational outcomes are generally associated with higher levels of positive synchrony between relationship partners (Saxbe et al., 2015), our study suggests that this is only the case when synchrony is assessed under conditions of lower stress. In contrast, our findings suggest that under higher stress conditions, dyads with higher levels of positive synchrony may be the most well-adjusted, as mothers in those dyads display the lowest levels of OC. This finding is consistent with two prior studies reporting correlations between greater cortisol synchrony and positive relationship qualities among parent–child dyads in high stress conditions (Atkinson et al., 2013; Ruttle et al., 2011); at the same time, however, our findings suggested that the pattern only held with older children, whereas these other two studies examined children younger than the youngest in our sample. Because our study is the first to test this relation among school-aged children, we are unable to propose reasons for the discrepant findings.

Attachment theorists emphasize the importance of tailoring parenting behavior to the child's developmental stage (Bowlby,

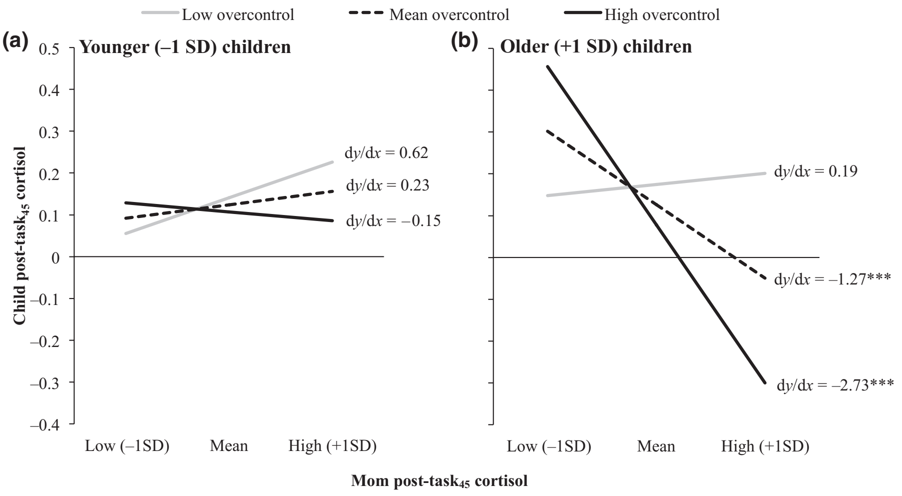

FIGURE 3 Results of multilevel modeling model plotting associations between mom (*x*-axis) and child (*y*-axis) post-task$_{45\text{min}}$ cortisol moderated by mom behavioral overcontrol and child age. Interactions graphed at (a) −1 *SD* child age, younger group *M* = 9.16 years and (b) +1 *SD* child age, older group *M* = 11.38 years. Asterisks indicate significant simple slopes, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

1969, 1973; Cassidy, 1994; Kerns, 2008). Older youth ought to have acquired more sophisticated self-regulation skills, requiring lower levels of hands-on behavioral assistance from parents and instead deriving security from the parent's psychological availability (i.e., knowing the parent will be available in times of dire need; Kerns et al., 2006; Kerns, Aspelmeier, Gentzler, & Grabill, 2001). Thus, to be sensitive to children's needs, parents of older children would wait for a child to request help before providing it, allowing children's behavior to indicate when they need more parental control. In comparison, when enacted by parents of older children, unsolicited help (OC) may reflect a larger pattern of insensitivity to children's growing autonomy. Younger children may be able to view OC as less intrusive (i.e., as help that appears in the absence of a request for assistance from the child), without strong negative impacts, but older children whose parents use OC may be at greater risk for negative outcomes, including anxiety and behavioral problems (e.g., Barber, 1996; Pomerantz & Eaton, 2000). Thus, it is not surprising that dyads in which mothers exhibit higher levels of OC when children are at the older end of middle childhood show a pattern of adrenocortical synchrony that diverges from the rest of the sample: they exhibit the greatest positive synchrony at pretask conditions and the lowest synchrony at post-task$_{25\text{min}}$ and post-task$_{45\text{min}}$.

One interpretation of these findings is that these higher OC/older child dyads are physiologically interdependent to an unhelpful degree when stress is not present, but at the time when adrenocortical synchrony may be helpful (and potentially even necessary), in the presence of high levels of stress, they are out of sync, perhaps least in tune with their children. Behaving sensitively as a parent involves reading one's child's cues on a moment-to-moment basis, understanding the child's developmental capacities, and responding with the level and type of behavioral support the child needs (Bowlby, 1973). Thus, the pattern of effects we observed for higher OC/older child dyads could reflect a mismatch between parents' behavior and children's needs (Kerns, 2008; Kerns et al., 2001)—older children need parents to be their warriors in waiting, psychologically available in times of distress and autonomy-supportive at other times; parents of older children who are routinely controlling violate that need.

Nevertheless, our interpretation of the basic finding—that adrenocortical synchrony during low stress conditions is a sign of negative relationship quality and adrenocortical synchrony during higher stress conditions is a sign of positive relationship quality—is also speculative, given the presence of mixed effects in the literature. Therefore, conclusions regarding the meaning of adrenocortical synchrony within this age range await replication and further study of these associations.

4.2 | The origins and meaning of mother–child adrenocortical attunement

Reactivity and regulation of the HPA axis is centrally involved in the psychobiology of the stress response (Chrousos & Gold, 1992), rendering cortisol, a product of HPA axis activation, an important biomarker to understand, both in terms of the implications of individuals' levels of the neurohormone as well as the links between cortisol synchrony and other constructs. Cortisol levels themselves are influenced by both genetic and environmental factors. A number of genetic polymorphisms are linked to HPA axis functioning (Mehta & Binder, 2012; Sapolsky, Romero, & Munck, 2000), including a polymorphism in the serotonin transporter gene, which is associated with both basal and stressor-related cortisol levels (Chen, Joormann, Hallmayer, & Gotlib, 2009; Gotlib, Joormann, Minor, & Hallmayer, 2008). Twin studies show that environmental factors also play key role (Franz et al., 2010; Van Hulle, Shirtcliff, Lemery-Chalfant, & Goldsmith, 2012; Schreiber et al., 2006; Wüst, Federenko, Hellhammer, & Kirschbaum, 2000). That is, various aspects of family environment have been associated with children's cortisol levels, including parent marital quality (Pendry & Adam, 2007), and family conflict and hostility (Granger et al., 1998; Repetti, Taylor, & Seeman, 2002). Relevant to the current study, differences in stress-related cortisol reactivity have been linked to variability in parent–child relationship quality (Berry, Blair, & Granger, 2016; Blair et al., 2015; Finegood, Blair, Granger, Hibel, & Mills-Koonce, 2016; Mendoza, Lyons, & Saltzman, 1991); children's higher cortisol reactivity tends to co-occur with less optimal attachment relationships.

The fact that cortisol levels themselves are associated with both genetic and environmental factors may provide a clue as to the factors that predict cortisol synchrony. To date no studies have explored whether genetic factors are associated with degree of cortisol synchrony, but a handful of studies have identified environmental factors, such as relationship quality, that predict degree of synchrony. In future studies, it will be important to explore genetic factors for their association with cortisol synchrony, as well as the interaction between genetic and environmental factors.

In addition to considering the factors that may influence the degree of cortisol synchrony, it is also important to identify what cortisol synchrony itself reflects. Synchrony in cortisol levels indicates that parents and children are experiencing similar levels of physiological stress arousal, and cortisol production through the activation of the HPA axis. We propose that similar physiological responses during a stressful task could occur as a result of a parent's focus on the child. That is, during the PCT, children's stress responses may be visible through their behavioral cues; parents who are able to pick up on these cues may display similarly heightened cortisol levels or adrenocortical attunement. Attunement may be due to many different processes/motivations including parental awareness of children's arousal or via processes occurring outside of awareness, akin to the way odors or pheromones impact behavior (e.g., Cowley & Brooksbank, 1991), or to a process of contagion, as when one person's anxiety leads another person to become anxious (Gump & Kulik, 1997; Hatfield, Cacioppo, & Rapson, 1994).

Attunement could, in turn, help account for parents' subsequent behavioral responses; higher physiological activation might prepare mothers to help regulate their children, by heightening their awareness or simply being available for comfort. On the other hand, if her child were highly aroused, a mother could potentially become overwhelmed if she contingently responded to her child's arousal. In other words, parents' physiology synchrony may require study in conjunction with physiological reactivity. In fact, in a prior study using this dataset, we found that mothers exhibiting high cortisol reactivity across the PCT were more likely to display OC only if they also showed low levels of understanding regarding their children's cognitions and emotions (i.e., lower reflective functioning, Borelli et al., 2017). In comparison, when highly reactive mothers had high levels of reflective functioning, they had the lowest levels of OC, suggesting that maternal mental state understanding is a critical factor in predicting mothers' behavior under stress. Taking these two sets of findings together, regarding synchrony and mother behavior and neuroendocrine activation and mother behavior, leads us to suspect that maternal and/or child cortisol activation could moderate the links between physiological synchrony and maternal behavior. This study was underpowered to explore such complicated statistical models, but we believe that linking degree of physiological synchrony, degree of physiological reactivity, and dyadic behavior is an important next step in the literature that could reveal important insights about emotion co-regulation.

4.3 | Strengths and limitations

This study contributes new insight to our understanding of adrenocortical synchrony in this developmental stage, in conditions of low and higher stress. Furthermore, the use of a standardized laboratory stressor enables us to conclude that when exposed to a set of controlled conditions, differences emerge among dyads in their levels of synchrony. In addition, the inclusion of a behaviorally-coded measure of parental insensitivity (rather than self-report) reduces the potential for reporting bias.

We also wish to acknowledge the limitations of this study. One limitation is our use of age as a proxy for developmental stage or level of independence. An important next step in this line of research would be to conduct an independent assessment of children's self-regulatory capacities, general developmental competencies, and autonomy-seeking rather than using age as a proxy for developmental stage. Relatedly, we did not assess pubertal timing in this study. As pubertal timing may affect both desire for independence, perceptions of stressful conditions, and cortisol production, future investigations ought to examine pubertal timing as a moderator of cortisol synchrony alongside OC and child age.

In addition, we examined degree of synchrony during conditions of low and high stress induced through a standardized procedure; however, children may experience the stress differently as a result of their genetic background and their prior experiences, including their experiences with their attachment figures (Bernard & Dozier, 2010; Kidd, Hamer, & Steptoe, 2011; Nachmias, Gunnar, Mangelsdorf, Parritz, & Buss, 1996). That is, what constitutes “low stress” for some participants may have been anything but low stress for others. This limitation could be addressed by complementary work in which researchers examine adrenocortical synchrony under participant-defined conditions of low and high stress as they occur in their daily lives.

Another limitation pertains to the measurement of cortisol—in the current study, we statistically controlled for time of day and scheduled most assessments during afternoon hours, but were not able to completely standardize the timing. Given that cortisol levels vary diurnally (Pollard, 1995), this introduces some error in the design. Further, although our estimates suggest that the post-$\text{task}_{25\text{min}}$ assessment captured levels of cortisol during the stressor, the assessments were not precisely tied to the ending of the PCT; this could mean that in some cases, the post-$\text{task}_{25\text{min}}$ assessment tapped cortisol levels during the recovery period.

Another limitation is that due to the cross-sectional design, we are unable to identify whether OC is a causal risk factor for the development of the adrenocortical patterns we observed. As well, although including an ethnically diverse sample of dyads increases the external validity of the findings, the sample size was underpowered for the exploration of differences in associations between ethnic groups. An in-depth exploration of ethnic group differences is an important next step given that prior work shows that the negative effects of OC on youth may not hold within certain populations (e.g., African American youth living in the United States; Khafi, Yates, & Luthar, 2014). Another issue is that our study was adequately powered to detect main effects but underpowered to detect the interaction effects with OC and age, underscoring the need for replication with larger samples.

Finally, the coding system employed in this study involves tallying a discrete list of behaviors thought to be indicative of OC, but this ignores the dyad-specific nature of controlling behaviors (i.e., what may be controlling within one parent–child dyad may be supportive in another). We attempted to account for this issue by controlling for children's help-seeking behavior in analyses, reasoning that mothers' behavior that occurs in response to children's help-seeking is not controlling, but even this strategy does not account for dyadic factors that occur outside of a specific interaction. For example, it may not be controlling if a child struggles with attention problems and the mother has learned to guide his focus back by suggesting the child try a certain strategy. While all coding systems involve some degree of error, further research using multiple measures of OC may help triangulate the construct of OC and its relation to adrenocortical synchrony.

Future research could also investigate the links between adrenocortical synchrony and parents' and children's perceptions of their relationship, as well as predictors of patterns of asynchrony (e.g., whether children in lower synchrony dyads tended to have higher or lower cortisol levels than their mothers). Lastly, studies should explore whether certain patterns of parent–child adrenocortical synchrony predict theoretically linked child outcomes.

5 | CONCLUSION

We provide intriguing evidence regarding the meaning of positive adrenocortical synchrony among mothers and school-aged children over the course of a stressor task. Whereas higher synchrony during low stress conditions may characterize dyads with the poorest parental behavior–child developmental stage fit (i.e., high maternal OC/older child age), higher synchrony measured during and after a stressor may indicate better parental behavior-child developmental stage fit (i.e., low maternal OC/older child age). Our findings underscore the importance of considering the context (developmental period and stress load) in which adrenocortical synchrony is measured.

DISCLOSURE

In the interest of full disclosure, DAG is founder and Chief Scientific and Strategy Advisor at Salimetrics LLC and Salivabio LLC. The nature of these relationships is managed by the policies of the committees on conflict of interest at Johns Hopkins University School of Medicine and the University of California at Irvine.

ENDNOTE

[1] This has also been referred to in the literature as adrenocortical concordance, co-regulation, and attunement (Timmons et al., 2015).

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