SYNCHRONY OF ELECTRODERMAL ACTIVITY IN A SOCIOECONOMICALLY AND RACIALLY DIVERSE SAMPLE OF MOTHERS AND PRESCHOOLERS

by

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(Under the Direction of Cynthia M. Suveg)

ABSTRACT

Physiological synchrony occurs when caregivers and children match their biological states and provides important information about the caregiver-child relationship. Given the links between this relationship and child outcomes (e.g., Schneider, Atkinson, & Tardif, 2001), further study of synchrony is warranted. The present study examined physiological synchrony of electrodermal activity (EDA) between 56 mother-preschooler dyads. Mothers and children completed a baseline and an interactive task. Mothers' self-reported psychopathology symptoms and children's mother-rated internalizing and externalizing symptoms were examined as moderators of EDA synchrony. EDA synchrony was not found in the interactive task, but was significantly moderated by mothers' psychopathology symptoms at baseline. Specifically, during the baseline task, mothers with higher symptoms showed significant negative synchrony, while synchrony did not emerge for mothers with lower symptoms. Moderation by children's internalizing and externalizing symptoms was not significant. Limitations and future directions, including methodological considerations, are discussed.

INDEX WORDS: Physiological Synchrony, Dyadic Concordance, Electrodermal Activity, Skin Conductance, Preschoolers, Mother-Child, Psychopathology, Internalizing, Externalizing

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CHAPTER 1

INTRODUCTION

The caregiver-child relationship is a critical context for understanding children's development. At the biological level, the ways that caregivers' and children's biological systems match during interactions can provide important information about the relationship itself (Feldman, 2017). This matching of biological states is termed physiological synchrony (Feldman, Magori-Cohen, Galili, Singer, & Louzoun, 2011). Much data supports the notion that positive behavioral synchrony, defined as mutual harmonious interaction between parent and child, is adaptive for child development across contexts (Davis, Bilms, & Suveg, 2017). However, the relatively scant literature to date examining physiological synchrony finds disparate results that vary according to developmental level, task context, and risk status (e.g., Lunkenheimer, Tibiero, Skoranski, Buss, & Cole, 2018; Suveg et al., 2019). Given the potential implications of physiological synchrony for child outcomes, it is therefore critical to better understand this process.

Caregiver-child synchrony has been documented using a variety of physiological indicators, including markers of parasympathetic activity, sympathetic activity, and HPA axis functioning (for a review, see Davis, West, Bilms, Morelen, & Suveg, 2018), with each system offering unique information about the caregiver-child relationship. To date, much of the work in caregiver-child synchrony has focused on respiratory sinus arrhythmia (RSA), a measure of parasympathetic activity that has offered information about mutual self-regulatory abilities. However, surprisingly little work has studied synchrony of sympathetic nervous system (SNS) activity (e.g., Baker et al., 2015; Gordis, Margolin, Spies, Susman, & Granger, 2010; Ghafar-Tabrizi, 2008), which is responsible for “fight or flight” responses. Electrodermal activity (EDA), also termed skin conductance (SC), is one of the most common markers of SNS activity. Because EDA is very temporally discrete, non-invasive to measure, and solely innervated by the SNS, it is a particularly attractive measure for researchers. Yet, only one study to date has studied EDA synchrony in caregivers and children (see Baker et al., 2015). The present study aims to extend this literature by examining EDA synchrony in economically and racially diverse mothers and their preschool-aged children during a baseline and an interactive task.

The Sympathetic Nervous System

The autonomic nervous system is comprised of the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS). While the PNS promotes rest, self-soothing and self-regulation, the SNS responds to external stressors by activating a “fight or flight” response associated with general arousal. Because the SNS is designed to facilitate motor activity, activation of the SNS is associated with increased heart rate, blood pressure, and sweating (McCorry, 2007). There are several physiological indicators of SNS activity, including salivary alpha amylase (sAA; e.g., Gordis et al., 2010), finger pulse amplitude (FPA; e.g., Ghafar-Tabrizi, 2008), electrodermal activity (EDA; e.g., Baker et al., 2015), and skin temperature (e.g., Ebisch et al., 2012; Manini et al., 2013). EDA is one of the most common markers of SNS activity studied in the literature. Measurement of EDA indexes the electrical conductivity of the skin as regulated by activity of the eccrine sweat glands (Cacioppo, Tassinary, & Berntson, 2007). These glands are solely innervated by the SNS, and their activity modulates the conductance of an applied current that is measurable at the surface level (Critchley, 2002). Eccrine sweat glands are primarily located on the palms of the hands, soles of the feet, and forehead, but are typically measured non-invasively via the palms (Boucsein, 2012).

There are several methodological advantages to conducting research with EDA. For instance, EDA is a very temporally sensitive measure. Following the presentation of a stimulus, EDA responses peak within about 1-3 seconds (Cacioppo et al., 2007) and can be measured in small epochs (e.g., 2 seconds; Baker et al., 2015), making it ideal for studying real-time dynamic changes in psychophysiological states. In comparison, sAA peaks within about 5-10 minutes following a stimulus (e.g., Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007) and therefore does not allow for moment-to-moment study. While there are similarly temporally discrete psychophysiological indicators that have been used in the literature, they present methodological challenges. For example, changes in skin temperature can be measured within relatively short periods of time (e.g., 10 seconds), but data can be compromised easily by activities such as moving or touching the face, which are difficult to control in children (e.g., Nhan & Chau, 2010). Further, interbeat interval (IBI) allows for hundreds of data points to be measured within a short period of time but is difficult to interpret as it is impacted by multiple physiological systems (Keene, Clayton, Berke, Loof, & Bolls, 2017). Because EDA is solely innervated by the SNS, it is considered a pure marker of SNS activity, thus enabling researchers to isolate the activity of this system. EDA is not without its own methodological challenges, however. For example, EDA is sensitive to rapid movements and changes in respiration (e.g., sneezing, coughing), both of which must be accounted for during data cleaning procedures (Boucsein, 2012). Individual differences, such as skin thickness or amount of sweat glands, can also impact the range of values obtained during recording and lead to artificially low synchrony estimates (Fowles, 2008).

Still, the temporal sensitivity and purity of EDA likely outweigh its disadvantages relative to other measure of SNS functioning.

Physiological Synchrony of Parasympathetic Activity

Current theory posits that physiological synchrony develops through a combination of genetic predispositions, prenatal programming and postnatal behavior (Feldman, 2017). While physiological synchrony can be measured through a variety of different indicators of autonomic nervous system functioning, much of the caregiver-child literature to date has examined PNS activity via respiratory sinus arrhythmia (RSA; for a review, see Davis et al., 2018). Prior research has shown that whether and how synchrony occurs largely varies by context and in particular, the task used to assess synchrony, the developmental level of the child, and the presence of child and/or caregiver psychopathology symptoms. With regard to task differences, some studies have indicated a lack of synchrony during baseline tasks (e.g., Bornstein and Suess, 2000; Creaven, Skowron, Hughes, Howard, & Loken, 2014; Suveg, Shaffer, & Davis, 2016), which require individuals to sit still and not engage with one another. These studies have suggested that such non-interactive baseline tasks may not be most conducive to eliciting synchrony. It is noteworthy that each of the aforementioned studies samples young children (e.g., ages 3-5). Yet, prior work using a sample of mothers and preadolescents did find synchrony during a baseline task (Suveg et al., 2019). Notably, while baseline synchrony was present, it was weaker than synchrony during a conflict discussion task, indicating that synchrony may be stronger during greater levels of interaction. However, the amount of interaction required to facilitate synchrony may vary by developmental level. Possibly, as children develop established patterns of interaction with their caregivers over time, less interaction is required for synchrony to emerge. It is thus critical to consider developmental level when studying the synchrony process.

Individual characteristics, such as symptoms of child and caregiver psychopathology, have also been documented to affect the synchrony process (e.g., Lunkeheimer et al., 2018; Suveg et al., 2019; Woody, Feurer, Sosoo, Hastings, & Gibb, 2016). For example, Lunkenheimer and colleagues (2018) compared RSA synchrony in mother-preschooler dyads during unstructured free play, semi-structured clean up, and structured teaching tasks. Across tasks, mother-child dyads showed positive, dynamic synchrony over time. However, differences in synchrony emerged by task and level of psychopathology. Across the sample, synchrony was stronger during the less structured tasks (i.e., free play and clean up) compared to the more structured and demanding teaching task. Among children with higher externalizing problems, however, synchrony with caregivers was actually strongest during the structured teaching task. The researchers suggest that greater structure may help mothers and children be physiologically in sync when children are dysregulated. Regarding older children and their caregivers, research indicates that parent and child psychopathology is associated with negative physiological synchrony (e.g., Suveg et al., 2019; Woody et al., 2016; Amole, Cyranowski, Wright, & Swartz, 2017). For example, Woody et al. (2016) found that preadolescents and mothers' physiological processes were negatively related in the context of maternal depression. Suveg et al. (2019) similarly found negative synchrony in the context of higher maternal depressive symptoms and child internalizing symptoms. As suggested by Lunkenheimer et al. (2018), the effects of maternal depression on synchrony may take longer than the preschool years to emerge.

Physiological Synchrony in the Sympathetic Nervous System

While synchrony in the PNS is thought to reflect mutual self-regulation and coping, synchrony in the SNS likely reflects mutual arousal. Mutual arousal might indicate similar interpretations of a stressful experience, an empathic response to the stress experienced by one member of the dyad, or shared genetic tendencies. Relatively little research exists examining caregiver-child SNS synchrony, and the few studies that have been published have not consistently used the same indicator of SNS activity (e.g., Baker et al., 2015; Gordis et al., 2010; Ghafar-Tabrizi, 2008). However, current research generally suggests that, as with other systems, it is important to consider context when studying SNS synchrony.

As in PNS synchrony, important differences in SNS synchrony emerge by task characteristics. For example, Ghafar-Tabrizi (2008) examined synchrony of finger pulse amplitude (FPA) in mothers and adolescents during neutral, pleasant, and conflict discussion tasks. While they did not find differences in synchrony across topics for the entire sample, they did find an interaction with level of conflict. Specifically, dyads exhibiting high levels of conflict showed significantly stronger synchrony during the conflict discussion than the pleasant discussion. Low-conflict dyads, on the other hand, showed stronger synchrony during the pleasant discussion than the conflict discussion, though this finding was not significant. Gordis and colleagues (2010) studied synchrony of salivary alpha-amylase (sAA) before and after a conflict discussion task in mother, father and adolescent triads, accounting for interparental physical aggression. Synchrony at the pre-discussion baseline was only found in mother-adolescent dyads without a history of interparental aggression. Together, these findings indicate that sympathetic arousal may not be necessary for synchrony to emerge in families with low levels of aggression or conflict.

Regarding synchrony in younger children, Ebisch and colleagues (2012) found that facial skin temperature synchrony in mother-preschooler dyads differed during a baseline and a "mishap" task. During the "mishap" task, mothers observed through a one-way mirror as the experimenter gave the child his "favorite" toy to play with, and after he left the room, the child "broke" the toy. When the experimenter re-entered the room, he soothed the child, explaining that it was not their fault. Synchrony was not found during the baseline task, but it was found during the emotionally arousing portions of the "mishap" task (e.g., breaking the toy, experimenter re-entering, and soothing). Using the same sample, Manini et al. (2013) later extended these findings by demonstrating that mothers observing their own children during the "mishap" task showed stronger synchrony than when they observed biologically unrelated children. Manini et al. (2013) suggest that mothers are more attuned to their own children than an unrelated child and therefore respond more rapidly to their distress, supporting the idea that active attention during a task may impact the strength of synchrony. Thus, similar to the literature on PNS synchrony, it appears that SNS synchrony likely varies by both task and developmental level. During the preschool period, there may need to be greater task demands to synchronize with caregivers than with older youth, particularly among low-risk families.

Sympathetic functioning at the individual level may have important implications for synchrony in this system, and research suggests that SNS activity varies by children's psychosocial difficulties. For example, Stifter and colleagues (2011) studied the sympathetic reactivity in a sample of 4.5-year-olds during a stressful task (i.e., an interview with an unfamiliar person) and a disappointment task (i.e., receiving a gift that the child had previously indicated they did not like). Low sympathetic activity in response to the stressful situation was associated with poorer emotion regulation abilities during the disappointment task. Conversely, greater sympathetic activation during the stress task was associated with better emotion regulation during the disappointment task, but only when this response was coupled with decreased parasympathetic activity.

Though individual-level variations in children's psychosocial functioning are likely to influence SNS synchrony, only one study has examined this issue. Based on the theory that the affective problems associated with autism spectrum disorder (ASD) may lead to disruption in the synchrony process, Baker et al. (2015) studied EDA synchrony in children with ASD ages 4-10 and their parents during a free play task. Lower ASD symptoms were associated with significant positive synchrony, while high symptoms were associated with negative synchrony, though not statistically significant. This suggests that, as has been found in PNS synchrony (e.g., Suveg et al., 2019; Lunkenheimer et al., 2018), the presence of psychopathology may interfere with SNS synchrony and should be considered when studying the synchrony process.

The Present Study

To date, Baker et al. (2015) is the only study to examine EDA synchrony in caregivers and children beyond infancy (i.e., ages 2-18; see Davis et al., 2018 for a review). The present study sought to address a major gap in the literature by examining EDA synchrony in a community sample of mothers and their 3- to 5-year-old children. To account for differences in synchrony by task structure, the present study assessed synchrony in both a baseline and a collaborative interaction task. In line with the current literature suggesting that interaction may be necessary for synchrony in early childhood (see Suveg et al., 2016; Lunkenheimer et al., 2018), it was hypothesized that EDA synchrony would emerge during the interactive task, but not in the baseline task. Additionally, given the several studies that have found that synchrony is disrupted in the presence of psychopathology (e.g., Baker et al., 2015; Lunkenheimer et al., 2018), the present study examined caregiver and child psychopathology symptoms as a moderator of synchrony. It was hypothesized that EDA synchrony would be strongest among dyads with lower levels of psychopathology, and weakest (or negative) among dyads with greater levels of psychopathology.

CHAPTER 2

METHODS

Participants

The complete sample for this study included 108 mother-child dyads; however, 52 dyads were excluded due to missing physiological data (*n* = 6), poor quality physiological data (e.g., EDA values below 0.5 microsiemens; *n* = 44), or missing data for moderating variables (*n* = 2). Participants in the current analyses therefore included 56 mothers (*M* age = 31.61 years, *SD* = 5.74) and their preschool-aged children (*M* age = 3.55 years, *SD* = .53, 55.4% boys). Data for this study were collected as part of a larger investigation that included genetics data collection. As such, only biological mothers and their children are included in the sample. All participants were required to be fluent in reading and speaking English. Mothers who were currently pregnant were excluded from the study, as were children with a developmental disability that would hinder their ability to fully participate in the study. The sample is racially diverse, with 33.9% of mothers identifying as Black, 50.0% as Caucasian, 1.8% as Asian, 5.4% as Hispanic, and 8.9% as "Other". Economically, 25% of the families reported a total household income between $0 – $19,999, 23.2% were between $20,000 – $39,999, 12.5% were between $40,000 – $79,999, and 10.7% reported a household income of over $80,000. More than half (58.9%) of mothers reported that they were currently married, 30.4% indicated that they had never married, 1.8% were separated, 3.6% were divorced, and 3.6% were currently engaged. Mothers were varied in their levels of education, as 1.8% had graduated junior high school, 12.5% had their General Educational Development (GED) certificate, 5.4% were high school graduates, 14.3%

received some college training, 33.9% were college graduates, and 32.1% had received graduate school training. A total of 35.7% of the sample was not currently employed, 21.4% were employed part-time, and 42.9% were employed full time.

Procedures

Prior to the lab visit, mothers were mailed packets of measures to complete and returned to the research team at the lab visit. Mothers who did not complete their measures did so at the lab visit. Upon arrival to the lab and following consenting procedures, electrodes were placed on the mother and child for collection of physiological data. Mothers and children then participated in a 4-minute baseline segment that involved sitting quietly and not interacting. Both members of the dyad then participated in an Etch-A-Sketch interaction task in which mother and child had to work together (i.e., the mother controlled one knob to move the draw horizontally, while the child controlled the other knob to draw vertically) to draw a picture of a house using an Etch-A-Sketch in 4 minutes. Participants then completed the rest of the study tasks and were compensated $100 for their participation in the larger study and children chose a small prize. Procedures were all in accordance with the University of Georgia's Institutional Review Board.

Measures

Electrodermal Activity. EDA data was collected from mothers and preschoolers during a baseline and a collaborative Etch-A-Sketch task. MindWare BioLab Software (Version 3.0.6) was used to collect physiological data during the two tasks. Disposable electrodermal electrodes were placed on the thenar and hypothenar eminences of participants' non-dominant palms. Data were collected at a sampling rate of 500 samples/second and cleaned by trained research assistants using MindWare EDA Software (Version 3.2.3) (MindWare Technologies, LTD., Gahanna, OH). Data were scaled from volts to microsiemens (μS) at a gain of 25 μS/Volt. To reduce noise, data were smoothed using a low-pass rolling filter at a block size of 500. An algorithm within the MindWare software was used to detect skin conductance responses (SCRs), defined as a 0.05 μS increase in EDA during the course of a 60-second segment. Trained research assistants manually inspected the data for artifacts (i.e., SCRs due to movement, respiration, or equipment error rather than arousal). An SCR was deemed to be an artifact if its removal altered the mean skin conductance level (SCL) of the 60-second segment by more than 0.5 μS. EDA values below 0.5 μS were excluded from analyses (see Doberenz, Roth, Maslowski, Wollburg, & Kim, 2011). Data were then collapsed to 2-second epochs (see Baker et al., 2015). Any 2-second epoch prior to, containing, and following an artifact was discarded from the final database and entered as missing data. Mothers and children could have a maximum of 120 epochs for baseline and 120 epochs for the Etch-A-Sketch task.

Baseline Task. Mothers and children participated in a 4-minute baseline task. Dyads were brought into a quiet room and asked to sit still side-by-side at a table until the 4 minutes had been completed.

Etch-A-Sketch Task. Dyads were asked to work together to collaboratively draw a house using an Etch-A-Sketch. Mothers and children were instructed to each use one knob of the Etch-A-Sketch (i.e., each member of the dyad could only draw horizontal or vertical lines) and not to touch the other's knob. Dyads were given 4 minutes to complete this task, though they were encouraged to work as quickly as possible. Dyads who finished prior to the end of the 4-minutes were asked to draw additional details surrounding the house (e.g., a tree) until the time period had ended.

Maternal Psychopathology Symptoms. Mothers completed the Symptom Checklist-90-Revised (SCL-90-R; Derogatis, 1994) in order to measure mothers' own current psychological symptoms. The SCL-90-R is a 90-item self-report measure that assesses psychological distress in nine primary symptom dimensions (i.e., somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism) as well as three global scores (i.e., the Global Severity Index, the Positive Symptom Distress Index, and the Positive Symptom Total). Previous research has indicated that SCL-90-R has adequate reliability and validity (Derogatis, 1994). For the present study, the Global Severity Index (GSI; $\alpha = .84$) raw scores were used during analyses, with higher scores representing greater psychological distress and lower scores representing less psychological distress among mothers. Among dyads included in analyses, 6 mothers reported symptoms in the borderline clinical range ($60 \leq t < 63$) and 9 mothers reported symptoms in the clinically significant range ($t \geq 63$).

Child Psychopathology Symptoms. Mothers completed the Child Behavior Checklist (CBCL/1.5-5; Achenbach & Rescorla, 2000) to report on their children's psychological functioning over the past 6 months. The CBCL is a 100-item rating scale, where 0 is *not true,* 1 is *somewhat or sometimes true*, and 2 is *very true or often true*. This measure yields a broadband Internalizing Problems scale ($\alpha = .89$), which includes items regarding somatic complaints and anxious, depressed, and withdrawn behaviors, as well as an Externalizing Problems scale ($\alpha = .92$), which measures children's delinquent and aggressive behaviors. An overall Total Problems score can also be computed. The CBCL has adequate psychometric properties (Achenbach & Rescorla, 2000). The internalizing and externalizing raw scores were used during analyses. For dyads included in analyses, 4 children were rated as having internalizing symptoms in the borderline range ($60 \leq t < 63$) and 8 children were rated as having internalizing symptoms in the clinically significant range ($t \geq 63$). For externalizing problems, 2 children were rated as having symptoms in the borderline range ($60 \leq t < 63$) and 9 children were rated as having symptoms in the clinically significant range ($t \geq 63$).

Analytic Strategy

Physiological synchrony can be assessed using a variety of statistical approaches, each of which has strengths and limitations (for a review, see Davis et al., 2018). Multilevel modeling (MLM) is a particularly rigorous analytic approach that accounts for the lack of independence between observations. Specifically, MLM nests repeated measurements (e.g., continuous EDA data) within individuals and nests individuals (e.g., mothers and children) within dyads. For the present study, multilevel models were run in Hierarchical Linear Modeling 7.0 (HLM; Raudenbush, Byrk, Cheong, Congdon, & du Toit, 2011) following techniques used by Suveg et al. (2019) and Baker et al. (2015). HLM is statistically advantageous in that it handles missing data by using full information maximum likelihood, which allows mothers and children to have differing numbers of observations (Larsen, 2011). HLM also offers the advantage of assessing for both between- and within-dyad effects. While between-dyad (BD) effects examine whether average maternal EDA is related to average child EDA over a task, within-dyad (WD) effects describe how maternal and child EDA are dynamically related throughout the course of a task. WD effects specifically describe whether an increase in maternal EDA during an epoch, with respect to her average, is related to an increase in child EDA during the same epoch, with respect to the child's average. The WD effect also accounts for the magnitude of an increase or decrease in EDA from an individual's average, meaning that dyads with more similar change magnitudes from epoch to epoch will demonstrate stronger synchrony. The present study quantified synchrony using both BD and WD effects, which result in a synchrony coefficient. The synchrony coefficient indicates both strength and direction of the synchrony relationship, with positive synchrony (i.e., values greater than 0) representing maternal EDA positively predicting child EDA, and negative synchrony (i.e., values less than 0) representing the negative prediction of children's EDA by mothers' EDA.

For each indicator of psychopathology (i.e., maternal psychopathology symptoms, child internalizing problems, and child externalizing problems), separate models were run to calculate synchrony during the baseline and Etch-A-Sketch tasks, resulting in a total of six models. Consistent with the extant literature (e.g., Creaven et al., 2014; Suveg et al., 2019), child EDA was the dependent variable in each model. Level 1 modeled the intercept, slope, and residual within-dyad error term. The slope at Level 1, which represents the rate of change in child EDA associated with concurrent variation in mother's person-mean centered EDA over time (i.e., the WD effect), was used to assess dynamic synchrony. Mother's EDA was person-mean centered to reflect within-dyad variation only (Merwin, Smith, Kushner, Lemay, & Dougherty, 2017). The intercept was used to measure average synchrony (i.e., the BD effect). Level 2 modeled variability in the Level 1 intercept and slope. Maternal psychopathology, child internalizing, and child externalizing symptoms were grand-mean centered and entered as Level 2 predictors of the intercept (i.e., moderating average synchrony) and slope (i.e., moderating dynamic synchrony) in their respective models.

Level 1:

$$\text{Child\_EDA}_{ij} = \beta_{0j} + \beta_{1j}\,(\text{Mom\_EDA}) + r_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Mom\_AvgEDA}_{j}) + \gamma_{02}(\text{Psychopathology}_{j}) + \mu_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Psychopathology}_{j}) + \mu_{1j}$$

An estimate of the within-dyad effect (i.e., the slope) for each dyad was obtained from the Level 2 residual file produced by HLM. Significant WD interactions (i.e., significant coefficient for a predictor of the slope) for each model were probed using the residual file. The sum of the empirical Bayes residual and the fitted estimate was computed for each dyad's slope (Taylor, 2012). This coefficient represents the strength and the direction of synchrony between mothers' and children's EDA for each unique dyad. Interactions were probed by running independent samples *t* tests between groups with high and low levels of symptoms.

CHAPTER 3

RESULTS

Descriptive Statistics

Means, standard deviations, and correlations for maternal psychopathology symptoms, child internalizing and externalizing problems, and mothers' and children's average EDA during each of the tasks are presented in Table 1. A significant association was found between child internalizing and child externalizing problems, $r = .67$, $p < .001$. Baseline EDA levels were significantly associated with EDA levels during the Etch-A-Sketch task for both mothers ($r = .91$, $p < .001$) and children ($r = .78$, $p < .001$). Average EDA levels during the Etch-A-Sketch task were significantly higher than average EDA levels during the baseline task for mothers, $t(55) = 5.27$, $p < .001$, and for children, $t(55) = 6.5$, *p,* < .001, indicating the Etch-A-Sketch task elicited significantly more sympathetic arousal from participants than baseline. Chi square tests revealed significant differences between participants with usable physiological data and those without regarding maternal and child race ($\chi^2_{\text{Mom}}(4) = 11.47$, $p = .02$; $\chi^2_{\text{Child}}(3) = 11.88$, $p < .01$), and maternal marital status ($\chi^2(5) = 13.77$, $p = .02$) and level of education ($\chi^2(5) = 19.66$, $p < .01$). An independent samples *t* test revealed a significant difference in regards to household income, $t(100) = 3.02$, $p < .01$. Those with missing data more often were black (61.5%), had never married (53.8%), did not complete college (72%), and earned an annual income of less than $40,000 (70.8%).

EDA Synchrony

To examine the presence of BD and WD synchrony in the overall sample, six multilevel models were run in HLM. The unstandardized regression coefficients from each model are reported as gamma, γ (Raudenbush & Bryk, 2002). Coefficients correspond to the equations presented above. Child sex and household income were entered into the models as covariates and were not found to be significant. These variables were therefore removed from the final models to avoid reducing statistical power. See Tables 2-4 for final estimated effects.

Baseline. Maternal psychopathology. The BD effect was not significant (γ_{01} = .136, *p* = .51), and maternal psychopathology symptoms was not significantly related to children's average EDA (γ_{01} = .000, *p* = .72). The WD effect was not significant (γ_{01} = -.405, *p* = .24); however, maternal psychopathology symptoms were a significant predictor in the model (γ_{11} = .001, $p <$ .01), indicating an interaction effect. Using the mean GSI *t* score of the sample, synchrony among dyads with relatively maternal high symptoms ($t \geq 53$, $n = 33$) and low maternal symptoms ($t < 53$, $n = 23$) were compared. Dyads with high maternal symptoms showed negative synchrony (*M* = -1.01, *SD* = 2.24), which significantly differed from zero, $t(32) = -2.60$, $p = .01$. Conversely, dyads with low maternal symptoms showed positive synchrony (*M* = 0.47, *SD* = 2.35), though this value did not significantly differ from zero, $t(22) = .95$, $p = .35$.

Child internalizing. The BD effect was not significant (γ_{01} = .138, *p* = .52), and child internalizing problems was not significantly related to children's average EDA (γ_{01} = -.039, *p* = .66). The WD effect was not significant (γ_{01} = -.403, *p* = .24). Child internalizing problems did not significantly relate to the WD effect. (γ_{11} = .004, *p* = .90).

Child externalizing. The BD effect was not significant (γ_{01} = .157, *p* = .46), nor was child externalizing problems significantly related to children's average EDA (γ_{01} = -.042, *p* =

.64). The WD effect was not significant (γ_{01} = -.403, *p* = .25), nor was child externalizing problems significantly related to the WD effect. (γ_{11} = .003, *p* = .13).

Etch-A-Sketch. Maternal psychopathology. The BD effect was not significant (γ_{01} = -.026, *p* = .91). Maternal psychopathology symptoms was not significantly related to children's average EDA (γ_{01} = .000, *p* = .96). The WD effect was not significant (γ_{01} = .447, *p* = .121), and maternal psychopathology symptoms was not significantly related to the WD effect (γ_{11} = .000 *p* = .201).

Child internalizing. The BD effect was not significant (γ_{01} = -.021, *p* = .88), and child internalizing problems was not significantly related to children's average EDA (γ_{01} = -.008, *p* = .95). The WD effect was not significant (γ_{01} = .457, *p* = .10). Child internalizing problems did not significantly relate to the WD effect. (γ_{11} = .043, *p* = .14).

Child externalizing. The BD effect was not significant (γ_{01} = -.012, *p* = .96), nor was child externalizing problems significantly related to children's average EDA (γ_{01} = -.021, *p* = .86). The WD effect was not significant (γ_{01} = .441, *p* = .11), nor was child externalizing problems significantly related to the WD effect. (γ_{11} = -.019, *p* = .36).

CHAPTER 4

DISCUSSION

Physiological synchrony is perhaps a reflection of the caregiver-child relationship at the biological level (Feldman et al., 2011), and while studies of this process have primarily focused on parasympathetic activity, synchrony of sympathetic activity remains largely unstudied (see Davis et al., 2018). PNS and SNS synchrony are thought to reflect different processes, with PNS synchrony indicating mutual self-regulation and coping and SNS synchrony indicating mutual arousal. The present study examined synchrony of EDA (or skin conductance), a common marker of SNS activity, in a socioeconomically and racially diverse sample of mother-preschooler dyads. In large part, findings did not support study hypotheses. However, hypotheses could not be rigorously evaluated given the substantive amount of unusable data, which resulted in a very small sample size and lack of adequate power. Thus, findings are interpreted with caution.

Prior work has shown that synchrony in young children and their caregivers generally emerges during interactive rather than baseline tasks (e.g., Lunkenheimer et al., 2018). The first hypothesis was therefore that synchrony would emerge in the Etch-A-Sketch task, but not the baseline task. Notably, both mothers and children exhibited significantly greater EDA levels during the Etch-A-Sketch task compared to the baseline task, indicating that the Etch-A-Sketch task did induce sympathetic arousal for both members of the dyad. Yet, despite the validity of the tasks, findings were inconsistent with the first hypothesis. In fact, synchrony did not emerge in the Etch-A-Sketch task, but emerged during the baseline task when considered in the context of maternal psychopathology. Specifically, mothers with relatively high symptoms of psychopathology demonstrated significant, negative synchrony with their children at baseline. Thus, while the hypothesis regarding type of task was not supported, it was predicted that synchrony would be weakened or negative in the context of maternal psychopathology, thus offering support for the second hypothesis. However, it was also predicted that weakened or negative synchrony would emerge in the context of child internalizing and child externalizing symptoms, which was not found. Rather, there was no significant relation between synchrony and child internalizing or externalizing symptoms. This can be partially attributed to the lack of variability in child internalizing and externalizing symptoms in the sample, with mothers reporting very low levels of symptoms for their children. Prevalence rates of psychopathology among preschoolers are relatively low, in part due to the fact that they cannot coherently express their symptoms (McDonnell & Glod, 2003). Thus, while findings are not in line with the second hypothesis, the lack of variability in the sample is developmentally appropriate.

Also unexpectedly, synchrony was not found during the interaction task. This was surprising given prior work (e.g., Ebisch et al., 2012; Lunkenheimer et al., 2018). However, every physiological indicator operates differently. It could be that the particular task that was used in this study elicits very different physiological responses from mothers and children. In particular, perhaps children found the task engaging and fun whereas mothers found the task more stressful or less interesting overall. Either way, the result would likely be discordance in SNS functioning.

Synchrony in the baseline task was not expected given that prior work examining mother-preschooler synchrony in the PNS did not find an association between maternal depressive symptoms and physiological concordance (Lunkenheimer et al., 2018). However, negative PNS synchrony with older children has been well documented in the context of maternal psychopathology (e.g., Woody et al., 2016; Amole et al., 2017; Suveg et al., 2019). It may be that SNS synchrony shows the effects of maternal psychopathology earlier than PNS synchrony because self-regulation takes time to develop, while fight-or-flight responses are more automatic. Also, maternal depressive symptoms have been associated with generally low EDA levels (Sarchiapone et al., 2018) as well as undesirable parenting behaviors, including withdrawal and disengagement (see Lovejoy, Graczyk, O'Hare, & Neuman, 2000). These patterns may have translated to the laboratory setting, with mothers with high symptom levels demonstrating low arousal and disengagement from the task. Their children, on the other hand, may have been more aroused due to being in an unfamiliar laboratory situation, leading to physiological discordance. Possibly, mothers with high symptom levels provided less behavioral reassurance to children (e.g., smiling, eye contact), which otherwise might have lowered their arousal. In fact, an examination of SNS levels during the task showed that mothers had significantly lower EDA levels than children, though levels were developmentally appropriate and comparable with the extant literature (e.g., Posthumus et al., 2009; VaezMousavi et al., 2007). Regardless, the findings of negative synchrony in the context of maternal psychopathology suggests discordance in the way that the situation was interpreted by mothers and children. Future work needs to examine whether the discordant responses reflect an adaptive response. In particular, it might be adaptive for mothers with psychopathology and preschoolers to not be in sync physiologically as this might in some way magnify the risks associated with the intergenerational transmission of psychopathology (Suveg et al., 2019; Amole et al., 2017; Woody et al., 2016).

Importantly, all conclusions are tentative given that the study was underpowered to rigorously test hypotheses. In particular, 38% of dyads from the full sample had at least one data file that was collected at too low of a signal (i.e., EDA values below 0.5 μS) to be reliably analyzed, resulting in 56 dyads with usable data. Low amplitude data can result from participant characteristics, environmental conditions, and experimental error (see Boucsein, 2012). Individuals who are dehydrated or have particularly dry skin produce lower EDA signals. EDA signals are also lower in colder temperatures (e.g., below 20° C or 68° F), particularly when participants are inactive. The tasks in the present study required participants to stay seated and relatively still, and it is possible that laboratory temperatures were too cold for optimal data collection in this context. Further, while research assistants were rigorously trained and followed research protocols to fidelity, it is possible that experimental error played a role in the collection of low signal data. The use of expired or dried out electrodes as well as poor electrode placement can have a large impact on EDA data. Researchers may not have properly handled and connected physiological data collection equipment.

Additionally, the inherent structure of the laboratory tasks may also have impacted the quality of EDA data. EDA is highly sensitive to movement (Cacioppo et al., 2007), and although EDA was measured using participants' non-dominant hands, some participants ignored instructions to keep hands still. In particular, the Etch-A-Sketch-task required mothers and children to collaboratively draw a house on an Etch-A-Sketch using just one knob each. However, some participants took control of both knobs, thereby using both hands to complete the task. It is also possible that some participants who did use just one knob still used their non-dominant hand during the task (e.g., to move the knob, to lift or point at the picture, etc.). During the baseline task, children may not have been able to keep their hands fully still given their developmental level. In response, mothers may have been actively attending to their children to help keep them still. Such movement would have resulted in reduced data quality.

Because such a significant portion of data was discarded, the final sample size was significantly smaller than expected. As a result, models were run separately for each moderator and task to ensure that groups were large enough to detect effects. Given the small sample size, it was not possible to dichotomize maternal psychopathology into high and low groups according to clinical ranges. Thus, high and low groups were formed relative to the sample. It is therefore not known whether the findings would generalize to a clinical sample. Children in the sample also had very low internalizing and externalizing scores, which resulted in a limited ability to detect variation in synchrony by child psychopathology.

Interestingly, analyses revealed significant differences between dyads with usable physiological data and dyads without. Specifically, those with discarded data were more often black and lower income than those with usable data. Of note, among dyads who were excluded due to having low-signal data (i.e., EDA values below 0.5 μS), 71.8% were African American. Prior work has similarly found that African Americans are more likely to be excluded from analyses due to producing unmeasurably low levels of EDA (e.g., Kredlow et al., 2018), and that African Americans who are included in analyses display lower EDA levels than non-African Americans (e.g., El-Sheikh, 2007; Kredlow et al., 2018). A concern is therefore that African Americans are being disproportionately excluded from EDA literature, and that results are not very generalizable. In addition, individuals with unusable data were lower in their reported annual income than those with usable data. Possibly, the relationship between being lower income and having unusable data can be attributed to the fact that African American families reported significantly lower annual incomes than non-African American families. Specifically, 56.5% (*n* = 26) of African American participants reported an annual income of $0-$9,999, compared to only 5.0% (*n* = 2) of Caucasian participants. It is also possible that individuals from low-income backgrounds were not sufficiently aroused during the laboratory tasks. Individuals suffering from chronic stress, such as the stress associated with living in poverty, have been shown to demonstrate hyporeactivity in response to a stressor (e.g., Teixeira et al., 2015; Sturge-Apple, Skibo, Rogosch, Ignjativic, & Heinselman, 2011). Possibly, mothers were simply not aroused by laboratory tasks and therefore did not elicit measurable levels of EDA. Further study is needed to better understand why such differences occur and how researchers can improve study design to improve EDA data collection in diverse samples.

Collective results from this study offer several avenues for future work in this area. Most importantly, future studies should be careful to consider factors that impact the quality of EDA data, including ensuring accurate experimental procedures (e.g., correct placement and use of unexpired electrodes) and minimizing and monitoring participant movement. Given the importance of studying synchrony in the context of conducive caregiver-child interaction (e.g., Lunkenheimer et al., 2018; Suveg et al., 2019), it is important to design tasks that both facilitate dyadic interaction and limit movement. Additionally, while community samples offer the benefit of being generalizable, larger sample sizes are necessary to obtain a more thorough picture of synchrony. In particular, since physiological synchrony is variable by context, it will be crucial to collect samples large enough to detect moderating effects. The present study found limited variability in terms of maternal psychopathology, child internalizing and child externalizing. Thus, while it was not possible to rigorously evaluate synchrony in relation to these variables, continued research is necessary given the effects of caregiver and child psychopathology on child development (e.g., Lovejoy et al., 2000). In particular, it is important to understand how synchrony of the SNS might be impacted in clinical contexts, and future work should consider how findings would translate to a clinical sample. Further, while there is much information to learn in cross-sectional studies of SNS synchrony, longitudinal studies are needed to understand how SNS synchrony relates to important child outcomes and the caregiver-child relationship over time.

In conclusion, a significant proportion of dyads were excluded due to unusable data, which resulted in a very small size that precluded a rigorous test of hypotheses. Nonetheless, the study provides valuable information for the field broadly by highlighting the challenges associated with conducting research on physiological synchrony in a preschool age group during dyadic tasks.

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Table 1.
Means, Standard Deviations, and Correlations

Variable	*M (SD)*	1	2	3	4	5	6	7
1) M Psychopathology	0.42 (0.33)	--						
2) C Internalizing	6.89 (7.44)	-.01	--					
3) C Externalizing	9.91 (7.49)	-.04	.67***	--				
4) M Baseline[a]	2.71 (2.60)	-.15	-.15	-.08	--			
5) C Baseline[a]	7.08 (5.25)	.13	-.09	-.15	.05	--		
6) M Etch-A-Sketch[a]	4.49 (4.64)	-.14	-.09	-.08	.91***	.05	--	
7) C Etch-A-Sketch[a]	11.23 (7.58)	-.09	.03	-.06	.08	.78***	.05	--

Note. C = Child; M = Mom.
[a] Value reflects average EDA taken across all 2-s epochs for each task.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 2.
Estimates of EDA Synchrony with Maternal Psychopathology as Moderator.

	Baseline		Etch-A-Sketch	
Fixed effects	Coefficient *(SE)*	*t* ratio	Coefficient *(SE)*	*t* ratio
Level 2				
M Average EDA, γ_{01}	.136 (.20)	.66	-.026 (.14)	-.19
M Psychopathology, γ_{02}	.000 (.00)	.36	.000 (.00)	.38
Level 1				
M EDA, γ_{10}	-.405 (.34)	-1.18	.447 (.28)	1.60
M EDA × M Psychopathology, γ_{11}	.001 (.00)	3.05**	.000 (.00)	1.30

Note. All coefficients (γ) are unstandardized regression coefficients. Level two modeled between-dyad effects, level one modeled within-dyad effects.
M = Mom.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3.
Estimates of EDA Synchrony with Child Internalizing as Moderator.

	Baseline		Etch-A-Sketch	
Fixed effects	Coefficient *(SE)*	*t* ratio	Coefficient *(SE)*	*t* ratio
Level 2				
M Average EDA, γ_{01}	.139 (.21)	.66	-.021 (.13)	-.15
C Internalizing, γ_{02}	-.039 (.09)	-.44	-.008 (.16)	-.05
Level 1				
M EDA, γ_{10}	-.403 (.34)	-1.19	.457 (.27)	1.67
M EDA × C Internalizing, γ_{11}	.004 (.03)	.13	.043 (.03)	1.50

Note. All coefficients (γ) are unstandardized regression coefficients. Level two modeled between-dyad effects, level one modeled within-dyad effects.
C = Child; M = Mom.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4.
Estimates of EDA Synchrony with Child Externalizing as Moderator.

Fixed effects	Baseline		Etch-A-Sketch	
	Coefficient *(SE)*	*t* ratio	Coefficient *(SE)*	*t* ratio
Level 2				
M Average EDA, γ_{01}	.157 (.21)	.74	-.012 (.14)	-.09
C Externalizing, γ_{02}	-.042 (.07)	-.64	-.021 (.12)	-.17
Level 1				
M EDA, γ_{10}	-.403 (.34)	-1.17	.441 (.27)	1.61
M EDA × C Externalizing, γ_{11}	.003 (.02)	.13	-.019 (.02)	-.92

Note. All coefficients (γ) are unstandardized regression coefficients. Level two modeled between-dyad effects, level one modeled within-dyad effects.
C = Child; M = Mom.
* $p < .05$, ** $p < .01$, *** $p < .001$.