THESIS

THE EFFECTS OF A BRIEF MINDFULNESS INDUCTION ON MATERNAL AUTONOMIC ACTIVITY

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ABSTRACT

THE EFFECTS OF A BRIEF MINDFULNESS INDUCTION ON MATERNAL AUTONOMIC ACTIVITY

Brief mindfulness activities are often included in preventive interventions for parents, but researchers do not know the type and combination of mindfulness components that beget the strongest effects on self-regulation. Focused attention meditation is associated with improved attention and self-regulation, but applications of such in interpersonal stressors are scarce. Using a randomized micro-trial design, the present study tested the effects of a brief mindfulness induction (focused attention meditation) on maternal autonomic processes, specifically change in respiratory sinus arrhythmia and tonic skin conductance level compared to resting state, during a goal-oriented task with her child (n = 40 mothers). Mothers were randomly assigned to listen to either a focused attention meditation or a control educational podcast before participating in an adapted Parent-Child Challenge Task (Lunkenheimer et al., 2017) with their 4.5-6.5-year-old children. A repeated measures linear mixed-effects model with basic covariance structure indicated an interaction effect between time and treatment for change in parasympathetic activity, such that mothers in the experimental group, on average, expressed relatively higher parasympathetic activation immediately following the induction period, compared to mothers in the control group. There were no statistically significant effects related to change in sympathetic activity. These results suggest a brief mindfulness induction can promote maternal parasympathetic processes during and immediately after the meditation. Beyond confirming pilot protocol viability, this work contributes to our understanding of the real-time, intra-individual effects of brief mindfulness inductions in interpersonal contexts.

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CHAPTER 1 INTRODUCTION

There is a growing interest in applying mindfulness to parent training programs (Coatsworth et al., 2015), but the optimal intervention components are unknown (Leijten et al., 2015). Mindfulness techniques are a promising avenue for supporting self-regulation (Keng & Tan, 2018; Leyland et al., 2018). Psychophysiological measures can help elucidate the effects of mindfulness practices on biobehavioral processes (Buss et al., 2018). Specifically, autonomic nervous system activity that is consistent with reciprocal activation of the parasympathetic and sympathetic branches can indicate one's level of self-regulation during interpersonal stressors (Palumbo et al., 2017; Porges, 2007). A mother's ability to regulate her emotions, behaviors, and physiological responses can relate to her parenting practices during challenging situations (Borelli et al., 2017; Lunkenheimer et al., 2019; Mills-Koonce et al., 2009). Most prevention or intervention programs do not show effects on biobehavioral self-regulation, and it is unclear whether the mindfulness activities or components of the programs are effective in adjusting these biobehavioral processes. In order to improve program effectiveness, the proximal effects of a brief mindfulness induction can be tested within a randomized micro-trial experiment (Howe et al., 2010). A brief mindfulness induction such as a focused attention meditation might support adult self-regulation during difficult parenting moments. The present study investigated the effects of a brief mindfulness induction, compared to a control podcast, on maternal autonomic activity over the course of a goal-oriented task with her child.

Mindfulness and Mindfulness-Based Interventions

In the past few decades, research on mindfulness, or the practice of knowing what is on one's mind and approaching each moment with openness, curiosity, and nonjudgment (Kabat-Zinn, 1990), has greatly increased (Van Dam et al., 2018). "Mindfulness" is an umbrella term used to characterize numerous practices, processes, and characteristics focused on attention, awareness, and acceptance. Mindfulness is strongly associated with general health and well-being (Tang et al., 2014). Trait mindfulness is defined as the extent to which an individual exhibits mindful behaviors or experiences in daily life, whereas state mindfulness describes daily experiences of or intentional practices to achieve particular mindful states such as nonjudgmental awareness (Brown et al., 2007). General mindfulness is associated with lower trait neuroticism and negative affect and higher trait conscientiousness and creativity (Giluk, 2009; Lebuda et al., 2016). To strengthen trait mindfulness through practices of state mindfulness, people use popular techniques such as meditation and yoga to promote nonjudgmental present-moment awareness and compassion for self and others (Williams & Kabat-Zinn, 2011).

Mindfulness training is now often included in psychosocial interventions intended to relieve symptoms including those related to pain, depression, and anxiety (McClintock et al., 2019) and promote well-being (Kabat-Zinn, 2003). These interventions tend to have moderate to large effects on subjective well-being, depression, and anxiety. Nonetheless, there is tremendous heterogeneity in goals, duration, and intensity across mindfulness-based interventions. For example, Mindfulness-Based Stress Reduction (MBSR) is the most popular and widely tested mindfulness-based intervention, originally created for individuals with chronic pain management by Dr. Jon Kabat-Zinn at the University of Massachusetts (Kabat-Zinn, 1990, 2003). MBSR incorporates 8 weeks of extensive meditation training (2.5 hours per weekly class with homework) and a 7-hour retreat. Mindfulness-based interventions such as MBSR can provide a host of psychosocial benefits, including improved psychological well-being and reductions in pain, rumination, anxiety, and depression (Chiesa & Serretti, 2009; Eberth & Sedlmeier, 2012; Goyal et al., 2014; Vøllestad et al., 2012). Nonetheless, much less is known about underlying mechanisms of mindfulness-based interventions, the effects of individual program components, or how to combine different mindfulness practices in an intervention to beget even stronger effects (Britton et al., 2018). Accordingly, there is an urgent need to test how individual components distinctly affect outcomes in order to design programs for optimal effectiveness.

Variation in Mindfulness Practices

In addition to whole-intervention heterogeneity, specific mindfulness practices vary in type, duration, intensity, and purpose; for example, a focused attention meditation cultivates concentration on a single point of reference while supporting the development of meta-awareness (Dahl et al., 2015). Typically, a focused attention meditation guides the listener in nonjudgmental awareness of breath and bodily sensations (Brandmeyer et al., 2019; Vago & David, 2012). To date, focused attention meditation has been associated with a host of enhancements in biobehavioral and neurological functioning, specifically improvements in attentional processes (Dickenson et al., 2013; Lee et al., 2012), emotion regulation and mood (Arch & Craske, 2006; Greenberg & Meiran, 2014), and cardiovascular measures (Zeidan et al., 2010).

Research on the effects of mindfulness meditations often assumes that different types of meditations are associated with different tenets of mindfulness (Cebolla et al., 2017) and thus function through distinct neurophysiological and biobehavioral pathways. Attentional processes and emotion regulation have been consistently considered primary outcomes of mindfulness meditation (Brandmeyer et al., 2019). It is possible attention and emotion regulation serve as primary mediators for focused attention meditations. Focused attention meditations can be delivered as “brief mindfulness inductions” to test how channeling attention to one’s bodily processes might relate to subsequent biobehavioral self-regulation.

A brief mindfulness induction is a short single session (20 min or less) of exposure to a mindfulness practice (Heppner & Shirk, 2018). These “mindful moments” or “micro-interventions” can proximally influence biobehavioral processes (Arch & Craske, 2006). Brief mindfulness inductions can support cognitive processes such as attention or perception, emotion regulation, social behaviors and processes, and health behaviors (Heppner & Shirk, 2018). Brief mindfulness inductions can be embedded within randomized micro-trial experiments to test the effectiveness of individual components from mindfulness-based interventions on specific, proximal outcomes of interest (Howe et al., 2010). These experiments can help bridge the gap between etiological studies of underlying parenting processes and large-scale efficacy trials of preventive interventions for positive parenting and family well-being (Leijten et al., 2015).

Researchers have started implementing randomized micro-trial experiments to test and compare the effects of brief mindfulness inductions on proximal outcomes of interest (Hirshberg et al., 2018). Different types of meditation such as focused attention or loving-kindness might be related to distinct neurological substrates (Fox et al., 2016) and elicit unique biobehavioral reactions to acute physical stress (Hirshberg et al., 2018). In this example, a gratitude meditation was statistically significantly less effective in buffering reactivity to acute physical stress, compared to a loving-kindness or focused attention meditation (Hirshberg et al., 2018). Although brief mindfulness inductions have been evaluated in intrapersonal contexts to some degree, little research has considered the effects of brief mindfulness inductions on real-time interpersonal processes. Furthermore, parents, in particular, may benefit from these brief practices, due to parenting stressors and limited time for self-care.

Mindfulness Approaches with Parents

Recently, parent training programs have been infused with mindfulness practices to promote mindful parenting practices (Coatsworth et al., 2015). Mindful parenting is an attentive, nonjudgmental, emotionally aware, regulated, and compassionate approach to interacting with one’s child (Duncan et al., 2009). Mindful parenting is associated with improvements in parenting practices and parent-child relationship quality (Coatsworth et al., 2010, 2015, 2018).

Mindfulness meditation not only tends to be associated with improvements in general self-regulation (Leyland et al., 2018; Tang et al., 2007, 2014) but also tends to support mindful parenting, positive parenting practices, and parent well-being (Townshend et al., 2016)

Although links between mindfulness, self-regulation, and parenting have been explored to some degree, less is known about the immediate effects of a brief mindfulness induction on parent biobehavioral self-regulation. Some research has considered the physiological effects of mindfulness meditation (Ditto et al., 2006; May et al., 2016; Tang et al., 2009), including associations between meditation and greater parasympathetic activation in the moment, compared to other relaxing activities (Ditto et al., 2006). Less work, however, has integrated physiological, mental, emotional, and behavioral experiences to elucidate the effects of mindfulness meditation on biobehavioral self-regulation. Focused attention meditation may narrow individuals' present experiences, guide their thinking and sensations, and shift their approach or experiences (Brandmeyer et al., 2019). If a brief mindfulness induction can elicit adaptive changes in autonomic activity, mothers might be able to expand their capacity for self-regulation in the face of external stressors and demands (Connell et al., 2017; Mills-Koonce et al., 2009).

Biobehavioral Self-Regulation

Biobehavioral self-regulation, or the internal management of evocative experiences and subsequent physiological and behavioral reactions, is central to managing intra-individual and interpersonal stress (Holzman & Bridgett, 2017). Parenting tasks often involve challenging, emotionally driven, and goal-directed activities; in these moments, mothers must manage their own emotions, behaviors, and physiological responses while helping their children do the same. These physiological responses partly in the autonomic nervous system, which regulates automatic bodily functions, such as respiration, digestion, and circulation, and consists of two branches, the sympathetic nervous system and parasympathetic nervous system.

Sympathetic Nervous System Activity

In stressful or arousing situations, the sympathetic nervous system typically prompts pupil dilation and increases in heart rate, blood pressure, and sweat production; this biobehavioral pattern is commonly referred to as the “fight or flight” response, which generates physiological resources to manage the stressor at hand (Porges, 2007). Derived from analysis of electrodermal activity, tonic skin conductance level is a noninvasive index of the average variation of skin’s electrical responses associated with perspiration and serves as a proxy for sympathetic reactivity when calculated to reflect individual fluctuations from a baseline measurement (Benedek & Kaernbach, 2010; Boucsein et al., 2012). Generally, when the sympathetic nervous system is engaged, tonic skin conductance level tends to rise, in conjunction with other physiological changes such as pupil dilation.

Parasympathetic Nervous System Activity

In contrast, when the parasympathetic nervous system is activated via the tenth cranial (vagus) nerve, respiration and heart rate slow, and the body conserves energy in a “rest and digest” state. When the vagus nerve suppresses the cardiac sinoatrial node, the parasympathetic nervous system is engaged and heart rate decreases; when the vagus nerve activates the sinoatrial node, the parasympathetic nervous system is inhibited and heart rate increases. Vagal tone, or the degree to which the vagus nerve is acting as a “brake” on the sinoatrial node, is a key component of parasympathetic nervous system activity (Beauchaine, 2001). Because cardiac vagal tone cannot be measured directly, respiratory sinus arrhythmia is a viable and noninvasive estimate of vagal tone (Berntson et al., 1993; Grossman & Taylor, 2007; Porges, 2001, 2007). Respiratory sinus arrhythmia is a measure of the small fluctuations in heart rate as related to respiration; heart rate increases slightly during inhalation and decreases slightly during exhalation. In nonthreatening contexts, the vagus nerve should be “braking” the sinoatrial node, and the parasympathetic nervous system should be engaged, resulting in higher respiratory sinus arrhythmia; in stressful circumstances, the opposite should take place. Lack of change in parasympathetic activity from resting state can indicate a lack of access to physiological resources to manage life and relational stressors, whereas the inverse can reflect a greater capacity for self-regulation (Beauchaine, 2001; Palumbo et al., 2017). Due to its relatively pure index of parasympathetic activity, change in respiratory sinus arrhythmia relative to baseline is becoming an increasingly popular and informative measure in developmental research, particularly in the areas of developmental psychopathology (Beauchaine, 2012; Hastings & Miller, 2014) and social relationships, especially between parents and children (Davis et al., 2017, 2018).

Intra-Individual Change in Autonomic Activity

Generally, autonomic activity indicates the patterns of the parasympathetic nervous system and sympathetic nervous system across time. Reciprocal activation is defined as the coordination between these systems in response to environmental demands (Berntson et al., 1991). For example, in socially or physically demanding situations, simultaneous sympathetic activation and parasympathetic withdrawal is adaptive, whereas, at rest, the inverse pattern is expected (Berntson et al., 1991). Individuals who exhibit maladaptive patterns of autonomic activity, in the form of a mismatch between system activity and contextual demands, tend to be at higher risk for psychopathology and relational conflict (Beauchaine & Thayer, 2015; El-Sheikh & Erath, 2011; McKernan & Lucas-Thompson, 2018). These patterns exist in social relationships (Palumbo et al., 2017) and may be emphasized in parent-child relationships, wherein parents strive to manage their reactions to stressful situations or problematic child behavior while also teaching children how to regulate their own emotions and behaviors.

Autonomic Activity and Parenting

To that end, maternal biobehavioral self-regulation can relate to parenting behavior and practices. High physiological stress reactivity, indexed by measures of the autonomic nervous system and hypothalamic–pituitary–adrenal system, tends to be associated with negative or inconsistent parenting behaviors and higher risk for child maltreatment (Lunkenheimer et al., 2019; Mills-Koonce et al., 2009; Reijman et al., 2016). Mothers might try to suppress their own physiological responses in response to emotional stimuli in order to provide beneficial regulatory support to their children (Kiser et al., 2019). Similarly, mothers who attempt to adjust their own biobehavioral responses based on their children's needs exhibit lowers levels of controlling parenting practices (Borelli et al., 2017).

Furthermore, parent-child interactions can relate to children's developing regulatory system (Propper & Holochwost, 2013); for example, parent behaviors can moderate children's physiological reactivity and child outcomes such as aggression (Kassing et al., 2018). Thus, mothers' biobehavioral regulatory processes — adaptive or maladaptive — can directly or indirectly interact with and affect their children's developing regulatory system (Davis et al., 2018; Gatzke-Kopp & Ram, 2018; Propper & Holochwost, 2013; Shih et al., 2018).

Outside stressors such as child behavior and individuals' perceptions of such can make it more difficult to regulate one's emotional, behavioral, and physiological responses. Mothers can experience stressors in their parenting roles (Mikolajczak et al., 2018) that undermine their capacity for adaptive biobehavioral self-regulation and positive parenting practices (Deater-Deckard & Panneton, 2017). Daily, goal-directed challenges between mothers and children (e.g., solving a problem, completing a structured activity, learning a new skill) are some of these contextual demands in which maternal biobehavioral self-regulation precedes parent-child coordination of biobehavioral processes and subsequent child adjustment. For instance, parent parasympathetic reactivity during a stressful scenario tends to prompt children's parasympathetic reactivity during a repair period, indicating maladaptive parent-child coregulation of parasympathetic processes and the need for parent-driven adaptation in challenging situations (Shih et al., 2019).

When mothers’ autonomic activity is consistent with patterns of reciprocal activation, mothers might be able to better regulate their emotional and behavioral reactions. To promote adaptive parent biobehavioral self-regulation, there is a growing interest in applying mindfulness and contemplative practices in parent training contexts (Duncan et al., 2009; Parent et al., 2016).

To date, mindfulness and mindfulness-based interventions have been effective in improving certain psychosocial outcomes, but less is known how mindfulness can affect biobehavioral processes in interpersonal contexts. Much of the research on the effects of meditation involves intra-individual stressors such as psychological or physical discomfort (Hirshberg et al., 2018). In order to increase the potential impact of mindfulness-based interventions for parents, we need to investigate the proximal and distal effects of individual program components (Leijten et al., 2015). A randomized micro-trial experiment (Howe et al., 2010) provides the framework to test the effects of and compare different types of brief mindfulness inductions on intra-individual autonomic processes during interpersonal interactions. Ultimately, studies like this can help inform and improve the quality and potential impact of mindfulness-based interventions.

The Present Study

The present study was conducted as part of Project Mind-Heart (PMH), which was designed as a randomized micro-trial experiment to test the proximal and distal effects of a brief mindfulness induction on parents’ biobehavioral self-regulation and co-regulation processes between parents and children during a challenging, goal-oriented task. This study uses data on mothers from PMH to test the effects of a brief mindfulness activity on average maternal autonomic activity, relative to resting levels, immediately after the intervention and during a parent-child interaction.

I tested the following hypothesis: Mothers who received the brief mindfulness induction, compared to those who listened to the control recording, will demonstrate a more adaptive pattern of (a) parasympathetic and (b) sympathetic activity. Relative to resting parasympathetic and sympathetic levels and on average, mothers will differ in autonomic activity by treatment group across time. Compared to the control group, the experimental group will express, relative to resting level and on average, (a) greater parasympathetic activation and sympathetic withdrawal during the intervention, greater parasympathetic withdrawal and sympathetic activation during the (b) PCCT baseline and (c) stressor, and (d) greater parasympathetic activation and sympathetic withdrawal during the PCCT repair.

CHAPTER 2 METHOD

The study was approved and monitored by the Colorado State University (CSU) Institutional Review Board (IRB) (19-9073H). The study began with informed consent with adult participants and verbal assent with minor participants.

Participants

Recruitment

Families were recruited from a cohort that participated in the Parenting Young Children Project (PYCP), a longitudinal study of dyadic biobehavioral coregulation between parents and young children at ages 2.5, 3, and 4 years. Families in the PYCP who elected to be contacted for future studies (n = 100) were invited to be screened for PMH eligibility via phone or email. Participant recruitment and on-campus, laboratory-based data collection occurred between August 2017 and June 2018.

Eligibility

To participate in the PYCP, families met a minimum life stress threshold and/or had involvement with Child Protective Services, had a child near the age of 2.5 years at time of recruitment without a diagnosed developmental delay or disorder, had a functional, age-appropriate command of English, and did not have medical conditions or prescriptions that influenced respiration or cardiovascular functioning. PMH participation criteria included completed participation of the PYCP, child age between 4.5 and 6.5 years old, and no parent hearing issues.

Sample Characteristics

The sample for this study consisted of 40 mothers, all of whom completed the full protocol with their children (57.5% female). The average child age was 5.49 (SD = 0.64). Mean mother age was 35.4 years old (SD = 5.28 years). Over half of mothers (52.5%) held at least a four-year college/university degree. Most mothers were Non-Hispanic and White (75%) and married (72.5%). The median household gross annual income range was \$50,000 – \$59,999 (Range = under \$4,999 to over \$90,000). The majority of mothers (77.5%) reported recent use of need-based government services (e.g., Supplemental Nutrition Assistance Program).

Procedure

Study Design

The present study employed a randomized micro-trial experiment to test the direct effects of a brief mindfulness induction on proximal autonomic outcomes in mothers of young children. It was intended to elucidate the effects of a brief meditation in a parenting context to inform and improve family-focused, mindfulness-based interventions.

Randomization. Mothers were randomly assigned to either the experimental or control group, using an urn randomization software (Stout et al., 1994). Widely used in clinical trials, the urn design forces a small-sample trial to be balanced but approaches complete randomization as sample size increases (Wei & Lachin, 1988). For each mother, the software balanced random assignments across five dichotomous variables: child age range (under 5.5 or above 5.5 years old), child biological sex (male or female), mother contemplative activities (yes or no), mother mental health services (yes or no; treatment, medications), and family strengthening activities (yes or no). This approach attempted to minimize any systematic differences between treatment groups, despite the small sample size.

Only the experimenters were aware of the experimental nature of the procedure and the treatment group assignments. Different team members enrolled, assigned, and delivered the treatment to participants, who were unaware of the randomization or multiple groups.

Brief Induction. Using an iPod shuffle and headphones, the brief intervention was delivered to each mother individually and privately in an on-campus observation room.

Experimental Treatment. Mothers in the experimental group listened to a brief focused attention meditation, a guided tension release meditation that focused on breath awareness and its connection to bodily tension. Breath awareness is a common mindfulness practice that guides the listener in maintaining focus on one's breath and bringing attention back to the breath when one's thoughts stray to other things. Beginning and ending with a gong chime, the female speaker guided the listener in softening and settling into a comfortable posture, gathering awareness of the breath and its associated movements, noticing body tension, guiding the breath to focus on and soothe those areas, and taking breath-based body awareness into the next moments of the day. The recording was approximately 5.5 min in length.

Control. Mothers in the control condition listened to an educational TED Talk about high-quality sleep and its associations with memory consolidation and neurological rejuvenation. The recording was approximately 5.5 min in length.

Laboratory Protocol

Mothers completed study questionnaires via Qualtrics prior to or during the on-campus laboratory session. The data acquisition equipment for physiological measurements was secured on the individuals for the session duration. After applying alcohol prep pads to the sites, three disposable, wet pregelled electrocardiographic (ECG) electrodes (35mm for adults and 24mm for children) were placed on each participant in a Lead II configuration, one directly below right clavicle (recording) and two below the last rib on each side (left recording; right grounding) to record the ECG waveform. Mothers washed their hands with alcohol-free, dye-free, fragrance-free soap minutes before the experimenter placed two electrodermal electrodes on the thenar and hypothenar eminences of their non-dominant hand to measure electrodermal activity. Mothers were asked to hold this hand in a neutral position and minimize its use. A crystal respiratory effort belt was placed around their diaphragms to monitor respiration. Electrode leads (five for adult and three for child) and the two wires from the respiratory effort belt were connected to data acquisition devices (MindWare Mobiles), which were held in backpacks worn by each participant. The devices connected wirelessly to a desktop computer in the adjacent observation room. The data acquisition software (MindWare BioLab 2.5, Noldus Observer XT 10.5, and Media Recorder 2.5) were monitored by a trained experimenter. Data collection began at least 10 min after electrode placement, per established guidelines (Boucsein et al., 2012).

The dyad jointly viewed a 3 min video, a clip from a nature documentary, *Beauty of the Cove*, to capture an approximate resting state; the child departed the room with the experimenter. Randomly assigned to a condition, mothers sat on the couch and listened to either the experimental or control recording for approximately 5.5 min. Mother and child then engaged in a 10-min parent-child interaction. The parent-child interaction followed an adapted Parent-Child Challenge Task (PCCT) protocol, which has been used effectively in cross-sectional and longitudinal studies to examine parent-child biobehavioral self- and co-regulation processes. The PCCT elicits biobehavioral variability across a series of tasks (Lunkenheimer et al., 2017). Using SmartGames Camelot Jr. puzzles for older children, the protocol consists of three phases: parent and child built a series of puzzles together for 4 min (baseline) in order to earn a prize; after a time limit is introduced, parent and child rushed to finish puzzles in 3-min stressor; and parent and child engaged collaboratively in a 3-min repair with a small prize, which was awarded, regardless of task performance. The PCCT tends to elicit mild stress for parents and children due to its challenging nature, minimal deception, and time-based performance expectations.

Debrief. The equipment was removed. Mothers were informed of the minimal deception employed during the experiment and were offered the opportunity to withdraw their information from the study; no mothers elected to do this. If two parents from the same household were participating in the study, the first parent was asked to not discuss the experience with the other parent until after they both completed the study. Each parent received $40.00 in compensation, and the child kept the small prize.

Measures

Condition (Predictor)

Condition was used as a fixed effect and dichotomous predictor, referring to the random assignment of mothers to the experimental (focused attention meditation) or control (educational podcast) groups for the brief induction period.

Maternal Age (Covariate)

Maternal age was calculated as years between date of birth and session date.

Autonomic Data (Outcomes)

Autonomic activity was the primary outcome of interest and consisted of indices of parasympathetic and sympathetic nervous system activity, which were modeled separately. These indices are ratio variables: respiratory sinus arrhythmia reflects the activity of the cardiac vagal nerve (Berntson et al., 1993) while tonic skin conductance level tracks the electrical activity of the skin associated with perspiration, excluding skin conductance events in response to external stimuli (Boucsein et al., 2012). Autonomic data were matched within-subject in 30-second epochs within each time period: 3 min resting, 5.5 min brief intervention, 4 min PCCT baseline, 3 min PCCT stressor, and 3 min PCCT repair.

Respiratory Sinus Arrhythmia. Mother electrocardiographic (ECG) and respiration data were processed to derive respiratory sinus arrhythmia, using the Heart Rate Variability (HRV) analysis application (version 3.2) from MindWare Technologies LTD. ECG data were edited for artifact and software misidentification per 30 sec epoch. Respiratory sinus arrhythmia was derived from the natural logarithm of the heart period variance using a frequency band-pass associated with respiration. Epochs that were shorter than 30 sec, contained excessive estimates (i.e., greater than 10 percent of R-peaks) or noise, or had a respiratory peak frequency (RPF) outside the expected band-pass range for adults (0.120 – 0.400 Hz) were excluded. Raw values of respiratory sinus arrhythmia were averaged within-subject across 30 sec epochs within each time period, producing values representing average respiratory sinus arrhythmia during the resting period, induction period, PCCT baseline, PCCT stressor, and PCCT repair.

Tonic Skin Conductance Level. Mother skin conductance data were processed to derive and validate tonic skin conductance level, using the Electrodermal Activity analysis application (version 3.2) from MindWare Technologies LTD. Using a rolling filter, block size of 500, and microsiemens (uS) threshold of 0.05, electrodermal activity data were edited for artifact and software misidentification per 30 sec epoch. Epochs shorter than 30 sec were excluded. Tonic skin conductance levels were averaged within-subject across 30 sec epochs within each time period, producing values representing average tonic skin conductance level during the resting period, induction period, PCCT baseline, PCCT stressor, and PCCT repair.

Statistical Approach

Balanced two-factor repeated measures linear mixed-effects models were used to test the hypotheses. The first model tested the differences between treatment groups in within-subject change in parasympathetic activity across time periods, while blocking by subject. The second model used the same framework, but the outcome was within-subject change in sympathetic activity. In both models, “treatment” and “time” were considered fixed effects, while “subject” was the blocking variable and a random effect. Maternal age was included as a covariate in both models.

CHAPTER 3 RESULTS

Preliminary Analyses

In accordance with Consolidated Standards for Reporting Trials (CONSORT) from 2010, descriptive statistics of demographic variables by treatment group are provided but were not tested for statistically significant differences. Mean maternal age in the control group was 34.45 years, compared to 36.35 years old in the experimental group. Mean child age in each group was roughly the same in each group: 5.47 years old in the control group and 5.5 years old in the experimental group. Child gender was split evenly between male and female for children of mothers in the control group, but the children of mothers in the experimental group were 65 percent female. Regarding educational attainment, 75 percent of mothers in the experimental group obtained at least a college education, compared to 30 percent of mothers in the control group. Fifty-five percent of families with mothers in the control group had a household income at or above the sample median range, compared to 45 percent of families with mothers in the experimental group. Seventy-five percent of mothers in the control group reported use of government assistance programs, compared to 80 percent of mothers in the experimental group. Seventy percent of mothers in the control group were married, whereas 75 percent of mothers in the experimental group reported being married. Fifty percent of mothers in the control group reported prior contemplative experience such as yoga or meditation, compared to 45 percent in the experimental group.

There was no missing data, and no cases were excluded from the analyses. During physiological data processing, however, several epochs were excluded, per established guidelines. For mother heart rate variability data, across all 40 participants, 27 epochs were excluded due to length (less than 30 sec), 2 epochs were excluded due to invalid respiration rate, and 17 epochs were excluded due to mid-beat edits exceeding 10 percent of R-peaks. For mother electrodermal activity data, 27 epochs were excluded due to length (less than 30 sec).

All data preparation and exploratory data analysis were completed in R version 3.6.2 (2019-12-12) via RStudio 1.3.911 with `tidyverse`, `readxl` and `rstatix` R packages. Before conducting the primary analyses, the relevant statistical assumptions were examined. Using `identify_outliers()` function from the `rstatix` R package for interquartile range calculations, no extreme outlying values of change in respiratory sinus arrhythmia or tonic skin conductance level were identified. Based on the Shapiro-Wilk test from the `rstatix` R package, the distribution of the residuals of both autonomic measures by each time period and treatment group were approximately normally distributed.

Covariates were considered based on theoretical and empirical rationale and measurement in the present study. Chronological age tends to be correlated with autonomic activity. Both respiratory sinus arrhythmia and electrodermal responses to stimuli tend to decrease over the lifespan (De Meersman, 1993; Hellman & Stacy, 1976). Based on this, maternal age was included as a covariate in both models. Additionally, based on Pearson correlation tests with Bonferroni multiple testing adjustments with `rstatix::cor_test()`, maternal age at time of session was correlated with change in tonic skin conductance level, $r = -0.18$, $p = 0.02$, but not respiratory sinus arrhythmia, $r = -0.005$, $p = 0.95$, in the present sample.

Calculating Intra-Individual Change in Autonomic Activity

Consistent with prior research, I computed reactivity scores, or level of intra-individual change from a resting state, to reflect change in parasympathetic and sympathetic activity rather than using raw outcome data and controlling for individuals' resting levels (Kuhn et al., 2018; McQuade & Breaux, 2017; Shoulberg et al., 2011; Wagner & Abaied, 2016). Reactivity scores were used as outcomes in the statistical models. Reactivity scores for each time period were computed by subtracting each mother's mean resting respiratory sinus arrhythmia and tonic skin conductance level values from her respective mean values from the induction period, PCCT baseline period, PCCT stressor period, and PCCT repair period. The latter four reactivity scores were included in the models, wherein positive change in average respiratory sinus arrhythmia or tonic skin conductance level reflected activation, and negative changes reflected withdrawal, relative to one's resting state. Reactivity, or "change" or "difference", scores are preferable to raw values because intra-individual change from a resting state is more informative and easier to interpret than a raw-unit change in terms of relative autonomic activation or withdrawal. This approach improves interpretability with scale conversion, controls for intra-individual variability, and removes the need to compare raw resting levels by group or include resting values when modeling (Burt & Obradović, 2013). In the present study, using reactivity scores as outcomes in the statistical models allows inference of relative parasympathetic or sympathetic activation or withdrawal within a given social context.

Statistical Modeling

Descriptive statistics for change in autonomic indices from resting period by time period and treatment group are presented in Table 1 in the Appendices.

The present study was designed with an underlying intent-to-treat principle, but no treatment or sample size changes were made after random assignment. The Type I error rate was set at 0.05 *a priori* for all statistical tests and modeling. Primary analyses were executed in R version 3.6.2 (2019-12-12) via RStudio 1.3.911, with the `nlme` and `emmeans` R packages. Balanced two-factor repeated measures linear mixed-effects models were used to evaluate the effect of treatment across time on parasympathetic and sympathetic activity, respectively. Model fixed effects included treatment (two levels: experimental and control) and time period (four levels: induction period, PCCT baseline, PCCT stressor, and PCCT repair). A *time*treatment* interaction was included in both models. The model was blocked by the random effect of individual mother to account for repeated within-subject measurements. Maternal age was added as a covariate in both models.

The assumption of compound symmetry was investigated to select the most appropriate model for each outcome. Originally, three repeated measures linear mixed-effects models with different covariance structures (i.e., basic, unstructured covariance, and autoregressive covariance) were fit for each outcome; however, autoregressive covariance structure assumes equally spaced time periods. Although the model of parasympathetic activity with the autoregressive covariance structure had the lowest Akaike Information Criterion (AIC) value, autoregressive covariance structures assume equally spaced time periods and were thus inappropriate given the present study's procedure. The AIC values were very similar across the three models of parasympathetic activity. To respect model assumptions, the model with a basic covariance structure was deemed most appropriate for the parasympathetic data. Second, the model with an unstructured covariance structure fit the sympathetic activity data most appropriately. After maternal age was included in each model as a covariate, the AIC values between the models with the basic and unstructured covariance structures for each outcome were compared again. For the model of parasympathetic activity, the AIC values were nearly identical, thus the model with basic covariance structure was retained. For the model of sympathetic activity, the model with unstructured covariance structure still had the lowest AIC and thus was retained.

Hypothesis 1: Effects of Brief Mindfulness Induction on Parasympathetic Activity

Regarding Hypothesis 1, I tested the main effects of a brief mindfulness induction on maternal parasympathetic activity using a repeated measures linear mixed-effects model with basic covariance structure (see Figure 1 in Appendices). There was a statistically significant *time*treatment* interaction on parasympathetic activity, $F(3, 114) = 4.03$, $p = 0.009$, meaning that the effect of treatment on parasympathetic activity depended on time period. As such, there was a statistically significant effect of time on change in parasympathetic activity, $F(3, 114) = 16.06$, $p < 0.0001$, indicating significant changes in average parasympathetic activity in mothers across time, regardless of treatment assignment. The effect of treatment on parasympathetic activity was not statistically significant, $F(1, 37) = 0.08$, $p = 0.78$, showing no evidence for statistically significant differences between treatments groups in average parasympathetic activity across time.

Three sets of pairwise comparisons, with Bonferroni multiple-testing and Satterthwaite degrees-of-freedom adjustments, were used to clarify the interaction effect. Within the experimental group, the average change from resting level in parasympathetic activity during the induction period was statistically significantly different from those of the PCCT baseline period, $t(114) = 5.70$, $p < 0.0001$, PCCT stressor period, $t(114) = 6.63$, $p < 0.0001$, and PCCT repair period, $t(114) = 4.74$, $p = 0.0002$. This indicates higher parasympathetic activity, on average, for mothers during the brief mindfulness induction, relative to resting state and compared to subsequent phases of the parent-child interaction.

Hypothesis 2: Effects of Brief Mindfulness Induction on Sympathetic Activity

Regarding Hypothesis 2, I tested the main effects of a brief mindfulness induction on maternal sympathetic activity using a repeated measures linear mixed-effects model with unstructured covariance structure (see Figure 2 in Appendices). There was a statistically significant effect of time on sympathetic activity, $F(3, 114) = 16.46$, $p < 0.0001$, indicating significant changes in average sympathetic activity over time, regardless of treatment assignment. Bonferroni-adjusted pairwise comparisons showed statistically significant differences within both treatment groups in average sympathetic activity during the induction period compared to those of PCCT baseline, PCCT stressor, and PCCT repair. The control group experienced sympathetic withdrawal during the induction period, compared to its average change in tonic skin conductance level during the PCCT baseline period, $t(114) = -3.21$, $p = 0.01$, PCCT stressor period, $t(114) = -4.13$, $p = 0.0004$, and PCCT repair period, $t(114) = -3.62$, $p = 0.003$. The experimental group, on average, experienced a decrease in sympathetic activity during the induction period, compared to its average change in tonic skin conductance level during the PCCT baseline period, $t(114) = -4.12$, $p = 0.0004$, PCCT stressor period, $t(114) = -4.80$, $p < 0.0001$, and PCCT repair period, $t(114) = -5.78$, $p < 0.0001$. The effect of treatment on sympathetic activity was not significant, $F(1, 37) = 1.91$, $p = 0.18$, showing no evidence for statistically significant differences between treatments groups in average sympathetic activity across time. Furthermore, there was no statistically significant interaction on sympathetic activity, $F(3, 114) = 1.61$, $p = 0.19$, providing no support for the possibility of the effect of treatment on parasympathetic activity depending on time period.

CHAPTER 4 DISCUSSION

A burgeoning area of mindfulness research examines how brief mindfulness inductions affect intra- and interpersonal processes (Heppner & Shirk, 2018). Brief mindfulness activities have been used successfully in interventions to change mindful parenting (Coatsworth et al., 2015, 2018); yet, it is not clear how a focused attention meditation might affect maternal autonomic processes in an interpersonal context. The present study investigated the effects of a brief focused attention meditation on maternal autonomic activity immediately following the induction and during a subsequent mother-child interaction. Hypotheses were partially supported; mothers who received the brief mindfulness induction demonstrated a relatively more adaptive pattern of parasympathetic activity, on average, immediately after the induction period, compared to mothers who listened to the control recording.

Focused attention meditation brings awareness to the breath and guides the listener in regaining focus on the breath when the mind wanders (Brandmeyer et al., 2019). Typically, parasympathetic activity, as indexed by respiratory sinus arrhythmia, increases during attention-to-breath exercises, with focused attention meditation having some of the strongest effects on respiratory sinus arrhythmia (Larsen et al., 2010; Mortola et al., 2020). Results indicated that mothers who listened to the focused attention meditation displayed relatively higher levels of parasympathetic activation, on average, across the induction, compared to the other time points. Compared to mothers in the control group, mothers in the experimental group, on average, expressed higher parasympathetic activation during the induction period and higher parasympathetic withdrawal from the induction period to the first phase of the Parent-Child Challenge Task, relative to resting levels. A focused attention meditation seems to have greater effects on maternal parasympathetic processes than does listening to an educational podcast. It may be the case that resting and listening attentively may have a modest effect on parasympathetic processes, but directed listening and breath awareness are more powerful.

Furthermore, the relatively higher parasympathetic activation during the induction period may have provided mothers with a higher parasympathetic starting point before entering the first challenging phase in the dyadic interaction. It is possible that the higher parasympathetic activation during the focused attention meditation allowed for parasympathetic flexibility from the peaceful induction period to the mildly stressful dyadic task. These results suggest an effect of a brief mindfulness induction on maternal parasympathetic activity, at least immediately following the induction. This aligns with existing knowledge of the positive effects of paced breathing and meditation on respiratory sinus arrhythmia (Mortola et al., 2020). Although, it is possible that the length of the meditation or the size of the sample was not sufficient to see sustained effects throughout the interpersonal challenge.

The second hypothesis was not supported. Regarding maternal sympathetic activity, results did not indicate statistically significant differences in change in sympathetic activity in mothers by treatment group across phases of the dyadic interaction. It should be noted, however, that mothers' sympathetic activity seemed to fluctuate in a pattern consistent with typical social arousal regardless of treatment group. Specifically, mothers tended to express sympathetic withdrawal during the induction period, sympathetic activation during PCCT baseline and stressor periods, and sympathetic withdrawal during PCCT repair period. Typically, indices of sympathetic processes such as skin conductance are strongest when the laboratory experiment elicits fear or pain (Kyle & McNeil, 2014; McGinley & Friedman, 2015); the PCCT likely did not have this kind of effect on mothers. In other words, the unit of change in sympathetic reactivity is very small: one microsiemen (uS) from one's resting tonic skin conductance level. It is possible this study was not designed to detect effects on sympathetic nervous system activity; the lightweight social demands during the parent-child interaction might not have generated the kind of sympathetic reactivity and recovery that could be captured with measurements of tonic skin conductance level. In future psychophysiological studies, cardiac pre-ejection period may be a viable alternative or complement to tonic skin conductance level as a noninvasive index of sympathetic activity (Newlin & Levenson, 1979).

Limitations

Although the present study was executed with rigor, it had its methodological and empirical limitations. The brief mindfulness induction was successfully delivered to all mothers in the experimental treatment group (n = 20); however, no process was in place to gauge the participants' level of engagement with the audio recording. Additionally, the sample size (n = 40 mothers) was small and likely inadequate to detect some effects; it is possible that, with a larger study, some effects would be clearer. This pilot study illustrated the feasibility of a larger study with a similar protocol, but it lacked the power analyses and participant recruitment needed to detect and better investigate the effects. For example, the difference between treatment groups in parasympathetic activation (p = 0.06) during the induction period may have been "statistically significant" in a larger sample. Furthermore, the current sample was drawn from one in a previous longitudinal study on parent-child dynamics. This convenience sampling approach is simultaneously effective and questionable, as it included dyads who participated in an earlier version of the Parent-Child Challenge Task twice previously. Although the dyads were informed otherwise at first, this interaction task may have been familiar, and therefore unchallenging, to some dyads. It is possible that, in a different study with dyads unfamiliar with the PCCT, there might be a higher level of autonomic reactivity and recovery, compared to that of the current sample.

Despite the sampling issues detailed above, the generalizability of the present study is acceptable. Parents may benefit from brief mindfulness inductions, at least during and immediately following the activity. The 5.5-min induction may not have been long enough to induce stronger and sustained effects on autonomic patterns, but the breath awareness activity was well-received by participating parents. It is possible that brief mindfulness activities in daily life might be feasible, acceptable, and effective for parents in promoting parasympathetic activity. It is unclear whether these effects can carry over into interpersonal interactions, although building a regular mindfulness practice can have stronger effects on intra- and interpersonal biobehavioral processes (Bornemann et al., 2019; Bornemann & Singer, 2017).

In terms of analytic technique, using repeated measures linear mixed-effects models surpassed repeated measures analysis of covariance in terms of model flexibility and robustness and is a stepping stone to more fine-grained analytic techniques such as multilevel modeling. Although the present study did not directly test autonomic coordination through the use of models with multivariate outcomes, it investigated patterns of average intra-individual change in parasympathetic and sympathetic activity, relative to resting states. Predicting activity in each system lays the groundwork for future investigations with multilevel modeling of autonomic coordination and balance (Berntson et al., 1991).

Future Directions

This study was innovative due to its (a) use of a randomized micro-trial design to test the effects of a brief mindfulness induction on biobehavioral processes, (b) study of intrapersonal processes in an interpersonal context, and (c) applications of mindfulness to real-time parenting contexts. Considering the under-powered nature of this pilot study, the effects of a brief mindfulness induction on mother parasympathetic activity are promising, at least during the meditation itself. Adjustments such as a longer induction period and investigations of other possible explanatory variables such as individual differences in dispositional mindfulness or prior contemplative experience should be considered. Mothers with higher levels of dispositional mindfulness and/or prior experience with contemplative practices such as mindfulness meditation may express higher levels of autonomic activity, given the social context, compared to those who are less inclined towards mindfulness. Furthermore, it is possible that meditation techniques such as focused attention or loving-kindness have differential effects on biobehavioral self-regulation (Hirshberg et al., 2018; Kirby & Baldwin, 2018; Miller et al., 2014).

Future work could test the different pathways of mindfulness meditation to adaptive biobehavioral self-regulation.

Future psychophysiological studies of this nature should also consider measuring more environmental and individual information for use as potential covariates. Environmental factors such as season, ambient temperature, and laboratory ventilation system can be related to electrodermal activity (Boucsein et al., 2012); however, none of this information was collected for the present study. Individual factors such as body mass index and physical fitness are related to cardiovascular patterns, including respiratory sinus arrhythmia, and should be measured in future related studies (Quintana & Heathers, 2014).

Conclusion

Overall, results from Project Mind-Heart can help “deconstruct” effects of mindful parenting training and inform the translation of brief mindfulness inductions into larger mindfulness-based, family-focused interventions. This work furthers our understanding of the active components of mindfulness-based interventions and the effects of brief mindfulness inductions on biobehavioral processes in interpersonal interactions. Knowing how brief mindfulness inductions can promote positive biobehavioral responses and adaptive parent-child interactions can advise the development and improvement of tailored, mindfulness-based support for parents and families.

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APPENDIX 1

Effects of brief mindfulness induction on maternal parasympathetic activity

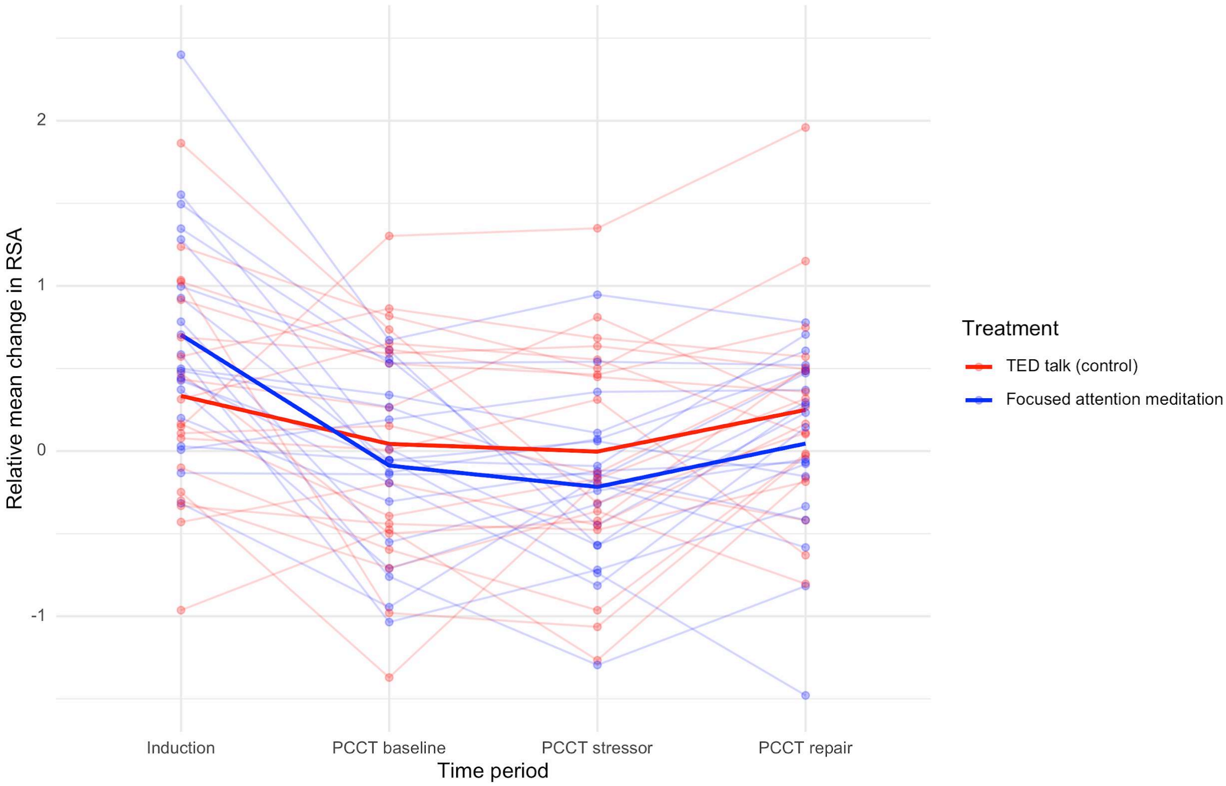

Figure 1
This figure demonstrates the average change in maternal respiratory sinus arrhythmia (RSA), relative to intra-individual resting levels. During the 5.5-min induction, mothers listened to either a focused attention meditation or educational podcast, and then the dyads engaged in a 10-min, 3-part Parent-Child Challenge Task (PCCT; Lunkenheimer et al., 2017).

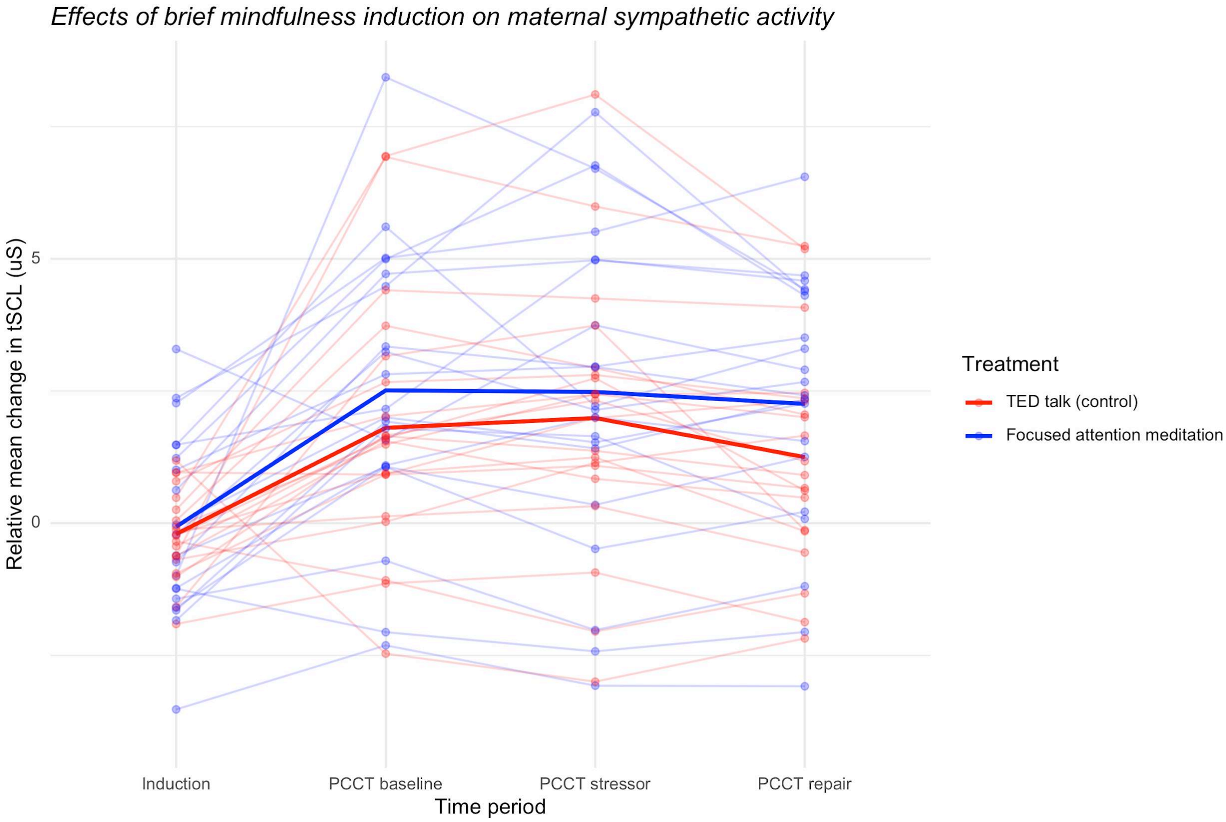

Figure 2
This figure illustrates the average change in maternal tonic skin conductance level (tSCL), relative to intra-individual resting levels. During the 5.5-min induction, mothers listened to either a focused attention meditation or educational podcast, and then the dyads engaged in a 10-min, 3-part Parent-Child Challenge Task (PCCT; Lunkenheimer et al., 2017).