Computers in Human Behavior 127 (2022) 107038

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

# Infants' physiological and behavioral reactivity to maternal mobile phone use – An experimental study

Yael Rozenblatt-Perkal [a], Michael Davidovitch [b,c], Noa Gueron-Sela [a,d,*]

[a] The Department of Psychology, Ben-Gurion University of the Negev, Israel
[b] Child Development Medical Department, Maccabi Healthcare Services, Israel
[c] Kahn-Sagol-Maccabi Research and Innovation Institute, Maccabi Healthcare Services, Israel
[d] Zlotowski Center for Neuroscience, Israel

## ARTICLE INFO

*Keywords:*
Heart rate
Parental mobile device use
Technoference
Infancy
Still Face

## ABSTRACT

The present study examined the impact of maternal mobile phone use during mother-child interaction on infants' physiological and behavioral reactivity (i.e., heart rate and negative affect). In this experimental study, 106 mother-infant (M age = 11.88 months; 51% male) dyads were randomly assigned to one of three experimental conditions. All conditions started and ended with a 3-min mother-child free-play and the manipulation occurred in between them: (1) Mobile-phone-disruptions: an experimenter sent mothers text messages and mothers were instructed to reply; (2) Social-disruptions: an experimenter entered the room and posed the same questions verbally; (3) Undisrupted-play: mother-child free-play. Infants' heart rate (HR) was recorded and observed negative affect (NA) was rated offline. Infants in the mobile disruptions condition exhibited the highest increase in HR and NA between the freeplay and the mobile-phone disruptions phase compared to the two control conditions. They also showed the sharpest decrease in HR between the mobile-phone disruptions and subsequent free-play phases. Finally, infants assigned to the mobile-phone-disruptions group showed the tightest coupling between physiological and behavioral reactivity, as evident in strong positive associations between HR and NA change scores. Mobile-phone disruptions during mother-infant interactions elicit physiological and behavioral reactivity among infants, suggesting that this may be a stressful context.

## 1. Introduction

Parental mobile device use while parenting (PMU) has become embedded in children's daily experiences, raising concerns about the potential impacts of this phenomenon on children (McDaniel, 2019). Whereas PMU has been associated with children's elevated negative affect and behavior problems (McDaniel & Radesky, 2018a; Myruski et al., 2018; Stockdale et al., 2020), its effect on children's physiological functioning is currently unknown. The potential impact of PMU on children's physiological stress reactivity is a pressing issue, given that most parents in modern societies frequently use their mobile phones while taking care of their children (Wolfers et al., 2020). In the current study, we sought to experimentally examine the effect of PMU on children's behavioral and physiological stress markers.

### 1.1. *The impact of PMU on children*

A growing body of research suggests that the use of mobile technologies can cause abrupt disruptions in social interactions. This phenomenon has been termed "technoference" to refer to the interruptions in interpersonal interactions that occur due to digital and mobile technology devices (McDaniel & Radesky, 2018b). Two literature reviews have recently outlined the effect that technoference may have on the quality of parent-child interactions and children's behavior (Kildare & Middlemiss, 2017; McDaniel, 2019). These reviews suggest that that PMU is associated with parents' reduced verbal and nonverbal communication with children, slow responses to children's engagement attempts, and less sensitive eventual responses. McDaniel (2019) suggests three mechanisms through which PMU can impact parenting quality. First, time spent on mobile devices can displace time spent with the child in other activities, resulting in fewer opportunities for

---

*Abbreviations:* PMU, parental mobile device use while parenting; HR, heart rate; NA, negative affect; SD, standard deviation.

* Corresponding author. The Department of Psychology, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva, 8410501, Israel.
*E-mail address:* gueron@post.bgu.ac.il (N. Gueron-Sela).

https://doi.org/10.1016/j.chb.2021.107038
Received 27 June 2021; Received in revised form 25 August 2021; Accepted 27 September 2021

0747-5632/

parent-child interaction. Second, constantly switching between paying attention to the mobile device and interacting with the child can lead to difficulties in accurately interpreting and responding to the child's cues. Finally, mobile phone use often evokes emotional responses such as stress, anger, and jealousy which can negatively affect parents' ability to be emotionally available to their children.

Sensitive reciprocal social exchanges with the primary caregiver are particularly important for children's social-communication development during the second half of the first year of life, a period in which joint attention skills emerge and develop rapidly (Mundy & Gomes, 1998). Joint attention refers to the social coordination of attention between partners when focusing on a common point of reference (Mundy, 2016). Joint attention behaviors begin to emerge in the first six months of life, when infants show an increasingly accurate ability to follow other people's direction of attention (i.e., following the gaze shift/head turn or pointing gestures of another to locate an object or event of interest). This has been referred to as responding to joint attention in the literature (Mundy, 2018). By the end of the first year of life, infants also develop the ability to initiate joint attention, as evident in the use of pointing, showing, and shifting their own gaze to spontaneously direct the attention of others to share their experience (Mundy, 2018). The dynamic practice of social attention coordination during infancy is hypothesized to provide brain–behavior experiences that are fundamental to the development of higher order social-cognitive skills (Mundy, 2016, 2018). Given that early social exchanges with caregivers provide the main context for infants to practice their developing joint attention skills, there is growing concern about how PMU may affect children's well-being.

#### 1.1.1. Correlational studies

Research relying on parental report measures of technoference and children's behavior problems show that technology interference in parent-child interactions is concurrently and longitudinally associated with elevated levels of children's externalizing and internalizing behavior problems (McDaniel & Radesky, 2018a, 2018b; Sundqvist et al., 2020; Wong et al., 2020). Notably, McDaniel and Radesky (2018) also found bidirectional associations between technoference and child behavior problems, suggesting that parents of children with elevated behavior problems may withdraw to mobile device use as a form of emotion regulation. Observational studies examining the effect of PMU on children's behavior in naturalistic settings such as playgrounds and restaurants show that young children exhibit negative emotions such as frustration, anger, and withdrawal while their caregivers are absorbed with their mobile devices (Elias et al., 2020; Radesky et al., 2014). Although this body of research provides evidence for the associations between PMU and children's negative behaviors, the correlational nature of these findings limits the ability to establish causal relations between these processes. For example, confounding variables, such as child temperament and parental education, are not always controlled for in correlational studies (McDaniel, 2019). Moreover, parental report studies often face the problem of single-reporter bias (McDaniel & Radesky, 2018a).

#### 1.1.2. Experimental studies

To overcome the limitations of correlational studies, there has been a recent call for more experimental work to better understand the causal links between PMU and child behavior (McDaniel, 2019). For example, the still-face paradigm (Tronick et al., 1978) has been adapted by researchers to experimentally examine the effects of PMU on children's behavior (Myruski et al., 2018; Stockdale et al., 2020). The classic still-face paradigm includes three phases: parent-child free play, still-face (the parent becomes completely unresponsive, with a neutral facial expression), and a reunion phase in which play is resumed (Tronick et al., 1978). In the modified still-face paradigm, parents are asked to be fully absorbed in a mobile device during the still-face phase. Findings from these studies mirror the classic still-face effect, with children exhibiting increased negative affect and decreased positive affect during the parental mobile device use phase (Myruski et al., 2018; Stockdale et al., 2020). These findings suggest that PMU may be equivalent to complete maternal unresponsiveness and that young children are sensitive to disruptions in the flow of social interactions during PMU.

#### 1.1.3. Psychophysiological responses to PMU

Whereas PMU has been associated with children's elevated negative affect and behavior problems (Elias et al., 2020; McDaniel & Radesky, 2018a; Myruski et al., 2018), its effect on children's physiological functioning is currently unknown. The use of solely subjective and observational measures to assess young children's stress responses provides limited insight into the underlying mechanisms involved in children's responses to PMU. In the current study, we used a non-invasive measure of autonomic nervous system (ANS) arousal, namely heart rate (HR).

The ANS is one of the major neural pathways activated by stress and can thus provide important information about the activation of the stress system and the process of stress regulation (Allen et al., 2014). Through the first postpartum year, the ANS changes rapidly to support infants' expanding abilities to regulate physiological and behavioral states in a dynamically changing environment (Porges & Furman, 2011). At birth, the ANS is underdeveloped, and infants are completely dependent on their caregivers to survive and obtain basic biological needs. As higher brain circuits begin to regulate the brainstem nuclei, which controls the ANS, infants become increasingly capable of self-regulating physiological states, and the dependence on the caregiver as a primary source of regulation decreases. Beginning from 6 months of age, infants exhibit increasing capacities to rapidly calm after disruptive challenges, to socially engage and to be soothed by others (Porges & Furman, 2011).

HR is a well-established cardiac indicator of ANS reactivity that reflects both parasympathetic (i.e., rest and digest functions) and sympathetic (i.e., fight-or-flight responses) activity (Dietrich et al., 2007; Stevenson-Hinde & Marshall, 1999). Infants' HR is normally faster than in adults, ranging between 93 and 161 with an average of 128 beats per minute (bpm) by the end of the first year of life (Fleming et al., 2011). This relatively fast cardiac rhythm may be related to higher respiratory frequencies, increased metabolic demands and to the overall immaturity of the ANS during infancy (Javorka et al., 2011; Kantor et al., 2003; Smith et al., 2009, pp. 365–368). Depending on the context, increases in HR may reflect either higher levels of negative or positive emotional arousal. In stressful contexts, multiple physiological and behavioral systems are recruited to restore and maintain homeostasis when perturbed (Haley & Stansbury, 2003). Research among infants has shown that under conditions of elevated stress, increases in HR are tightly coupled with increases in observed negative arousal. For example, infants' intensity of negative vocalizations was positively and strongly correlated with HR during a well-baby examination (White et al., 2000) and during the still-face phase of the classic still-face paradigm (Haley & Stansbury, 2003). These findings suggest that high levels of stress inhibit the activity of the parasympathetic nervous system to potentiate sympathetic expression, resulting in increased cardiac output and the associated adaptive responses of increased expression of negative affect (Bazhenova et al., 2001; Porges et al., 2007).

According to attachment theory (Bowlby, 1982), certain environmental cues (e.g., maternal separation or unresponsiveness) activate infants' attachment system resulting in varying levels of negative affect. Sroufe and Waters (1977) suggest that the activation of the attachment system also involves increases in infants' physiological arousal, regardless of differences in attachment styles with their caregivers. In support of these predictions, they showed that all infants demonstrated increases in HR when separated from their mother, although behavioral expressions of distress were not always evident. These findings are consistent with research using the classic still-face paradigm, showing that in addition to children's behavioral responses to the still-face, they also show physiological reactivity patterns that confirm the stressful nature of the still-face episode (Moore & Calkins, 2004). Specifically, infants show an increase in heart rate (HR) from free-play to the still-face episode (mean change ranges between 2.19 and 5.68 bpm), followed by a decrease (between 2.04 and 3.97 bpm) from the still-face to the reunion episode (Haley & Stansbury, 2003; Weinberg & Tronick, 1996). As previous research has established that PMU is associated with reduced parental responsiveness that mirrors the still-face paradigm, it is possible that PMU similarly activates the attachment system, evoking a biobehavioral stress response.

### 1.2. *The current study*

The potential impact of PMU on children's physiological stress reactivity is a timely matter, given the high rates of parental mobile device use during childcare and the negative effects on children demonstrated in correlational and experimental studies (Elias et al., 2020; McDaniel & Radesky, 2018a; Myruski et al., 2018; Stockdale et al., 2020). We, therefore, sought to examine the effect of PMU on children's psychophysiological stress markers (HR and observed negative affect). To that aim, we used a modified version of the classic SFP. Based on Myruski et al. (2017), we employed a novel SF phase designed to introduce an ecologically valid experimental condition of mobile phone device use. Specifically, we altered the protocol of the modified SFP by instructing mothers to reply to text messages during the SF period, a common scenario in everyday life (i.e., *mobile-phone-disruptions* condition). To explore whether the disruptions in social interactions created by PMU have a unique effect on infants' physiological responses, we added a between-group control condition in which the texting phase was replaced by a phase in which a research assistant present in the room presented the same questions verbally to the mothers (i.e., *social-disruptions* condition). The addition of this control condition will enable us to understand whether there is a specific disrupting effect for PMU, or whether the effects of PMU are similar to other types of common non-child-directed disruptions (Vanden Abeele et al., 2020), such as social conversations. We also included a between-group control condition of undisrupted mother-child free play to control for the natural changes that occur in mother-child interactions through time (i.e., *undisrupted play condition*). See Fig. 1 for a schematic description of the three experimental conditions and phases.

We suggest the following hypotheses:

**H1**. Infants assigned to the mobile-phone-disruptions condition will exhibit an increase in HR and observed negative affect (NA) during the texting phase compared to the free play phase, as well as in comparison with infants assigned to the undisrupted-play condition in the second phase of the experimental paradigm (conversation with experimenter/free play, respectively).

**H2**. Infants assigned to the mobile-phone-disruptions condition will exhibit a stronger association between increases in HR and NA, reflecting coupling between behavioral and physiological stress responses (Bazhenova et al., 2001), compared to infants assigned to the undisrupted-play condition.

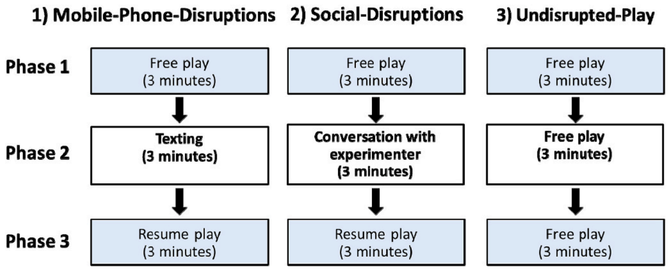

**Fig. 1.** Schematic description of the three experimental conditions and phases.

**H3**. Finally, as we aimed to explore whether there is a specific disrupting effect for PMU, we will examine in an exploratory manner whether infants in the social-disruptions condition exhibit similar or different patterns of HR and NA change as infants in the mobile-phone-disruptions condition.

## 2. Methods

### 2.1. *Participants*

The study protocol was reviewed and approved by the Human Subjects Research Committee at (omitted for review). One hundred and twenty-two mothers and their infants were recruited to participate in the study through advertisements on online social media platforms. Exclusion criteria included maternal age below 21 years, maternal report of diagnosed psychiatric conditions, mother and child health problems, child preterm birth status, and child diagnosis of neurodevelopmental disorders. Data from sixteen dyads were excluded from the analysis for the following reasons: maternal psychiatric conditions ($n = 4$), infant preterm birth status ($n = 1$), unreadable physiological signal ($n = 8$), video-recording equipment failure ($n = 3$). Thus, data from 106 participants were used for the current analyses. Demographic characteristics of study participants are described in Table 1. Mean child age was 11.88 ($SD = 1.2$) months, and 51% were male. Mean maternal age was 32.49 ($SD = 3.78$) years, and most of the mothers in the sample were born in Israel (75.4%) and obtained a college degree (76.2%).

### 2.2. *Experimental setting and procedure*

This study used a 3X3 mixed-design, with condition as a between-participants factor (mobile-phone-disruptions, social-disruptions, undisrupted-play) and phase (free play, texting/conversation with experimenter/free-play, free play) as a within-participants factor (see Fig. 1). Mother-child dyads were randomly assigned to one of three experimental conditions: mobile-phone-disruptions ($n = 37$), social-disruptions ($n = 33$), undisrupted-play ($n = 36$). Data were collected during a laboratory assessment, in which all mothers signed informed consent forms. All three conditions began with a mother-infant 3-min free play phase, in which infants were seated in a highchair by a table approximately 40 cm across from their mothers. A research assistant provided a basket with age-appropriate toys. Mothers were instructed by the research assistant to play as they usually do with their infants. The second 3-min phase of the experiment differed between conditions. In the mobile-phone-disruptions condition, the research assistant asked mothers to place a mobile phone on the table and then sent them text messages with different questions (e.g., “What does your infant usually eat for breakfast, lunch, and dinner?“). Mothers were instructed to reply to all text messages. To eliminate the chance that participants will receive personal text messages or phone calls, we used a designated confederate mobile phone. In the social-disruptions condition, the research assistant entered the room and posed the same questions verbally (as in the text messages in the mobile-phone-disruptions condition). In the undisrupted-play condition, mothers and children continued to play. All three conditions ended with a 3-min undisrupted free-play phase.

### 2.3. *Measures*

#### 2.3.1. *Heart rate (HR)*

Cardiac activity was recorded using a lightweight recording device attached to the infants' chest using two disposable pediatric electrodes (Actiheart, CamNTech Ltd.). A trained research assistant edited the data for artifacts using the CardioEdit software (Brain-Body Center, Chicago, IL). Editing consisted of scanning the data for outlier points and replacing them by dividing them or summing them to be consistent with the adjacent data. No more than 2% of any individual data file required

**Table 1**
Sample demographic characteristics by condition.

| Variable | Mobile-phone-disruptions ($n = 37$) | Social-disruptions ($n = 33$) | Undisrupted-play ($n$ = 36Table 3) | Total ($N = 106$) | Test statistics |
|---|---|---|---|---|---|
| Infant Age, Months *M(SD)* | 12.00 (.12) | 11.88 (.12) | 11.76 (.12) | 11.88 (.12) | $F = .93$ |
| Infant Gender, Males, *n (%)* | 23 (58.9) | 17 (51.5) | 17 (43.5) | 57 (51.3) | $\chi^2 = 1.90$ |
| Mother Characteristics | | | | | |
| Age, *M(SD)* | 30.58 (6.39) | 28.10 (9.53) | 31.68 (4.00) | 30.23 (6.93) | $F = 2.36$ |
| Married, *n (%)* | 34.0 (87.1) | 29.0 (87.8) | 37.0 (94.8) | 100.0 (90.0) | $\chi^2 = 5.35$ |
| Country of origin | | | | | $F = .37$ |
| Israel | 29.0 (74.4) | 27.0 (81.8) | 27.0 (69.2) | 83.0 (74.7) | |
| Other | 10.0 (25.6) | 6.0 (18.2) | 12.0 (30.8) | 28.0 (25.3) | |
| Education level, *n (%)* | | | | | $F = 2.13$ |
| High school or Less | 2.0 (5.1) | 3.0 (9.1) | 6.0 (15.4) | 11.0 (9.9) | |
| Professional training | 3.0 (7.7) | 4.0 (12.1) | 5.0 (12.8) | 12.0 (10.8) | |
| Undergraduate degree | 20.0 (51.3) | 16.0 (48.5) | 20.0 (51.3) | 56.0 (50.4) | |
| Graduate Degree | 13.0 (33.3) | 8.0 (24.2) | 7.0 (17.9) | 28.0 (25.2) | |
| Income, *n (%)* | | | | | $F = .01$ |
| Low | 3.0 (7.7) | 4.0 (12.1) | 2.0 (5.2) | 9.0 (8.1) | |
| Below average | 14.0 (35.9) | 10.0 (30.3) | 16.0 (41.0) | 40.0 (36.0) | |
| Average | 12.0 (30.8) | 12.0 (36.4) | 14.0 (35.9) | 38.0 (34.2) | |
| Above average | 8.0 (20.5) | 6.0 (18.2) | 6.0 (15.4) | 20.0 (18.0) | |

$^{*}p < .05$, $^{**}p < .01$.

editing. HR was computed for each 30-s epoch using the CardioBatch software (Brain-Body Center, Chicago, IL). Mean HR was then calculated for each of the three phases in the experimental conditions.

*Computation of HR change scores.* Residualized change scores were calculated to index HR reactive change (Burt & Obradovic, 2013). This method consists of regressing HR during a specific experimental phase onto HR in the previous phase and extracting the standardized residuals for use in analysis, accounting for infants' previous HR levels. A residualized change score represents whether an individual has changed more or less than expected based on his or her baseline score and the sample regression line. A positive score represents an increase that is larger than expected given the sample regression line, while a negative score represents change that is smaller than expected. Two residualized HR-change scores were calculated: a) Change between phase 1 and 2; b) Change between phase 2 and 3.

### 2.3.2. Negative affect (NA)

Infants' NA was rated from the videotaped assessments on a second-by-second basis, using a 5-point scale ranging from 0 to 4, with 0 = *no distress* (no distress expression); 1 = *slight distress* (visible distress manifested non-vocally through bodily postures or facial expressions); 2 = *moderate distress* (whimpering expressed vocally); 3 = *pronounced distress* (full-blown crying) and 4 = *intense distress* (intensive crying) (Zahn-waxler et al., 1992). Distress scores for each experimental phase were calculated by summing the distress scores multiplied by their proportional duration at each phase. For example, an infant who experienced slight distress (1) for half of the time in the disruptions phase, but in the second half did not experience distress at all (0), received, for the disruption phase, an overall score of 0.5: $0*0.5 + 1*0.5 = 0.5$. Higher scores correspond to greater distress across all conditions and phases.

Two trained research assistants coded the observations. Interrater reliability coefficients were examined in 15% of the videotapes, which were randomly selected. The interrater reliability coefficient was Kappa = 0.82.

*Computation of NA change scores.* NA-change scores between phases were calculated as described above for HR change. Thus, two residualized NA-change scores were calculated: a) Change between phase 1 and phase 2; b) Change between phase 2 and 3. More positive scores represent greater increases in NA from the previous phase.

### 2.3.3. Covariates

*Mobile Device Interference in Mother-Child Activities.* Overall mobile device interference in mother-child activities (i.e., technoference) was included as a covariate based on previous studies demonstrating associations between maternal reported technoference and infants' responses across the modified SFP episodes (Myruski et al., 2018; Stockdale et al., 2020). Mothers were asked, "On a typical day, about how many times do the following devices interrupt a conversation or activity you are engaged in with your child?" The following devices were asked about: (a) cellphone/smartphone, (b) television, (c) computer, (d) tablet, (e) iPod, and (f) video game console. Mothers responded to each item on a seven-point scale ranging from 1 (*none*) to 7 (*more than 20 times*). Items were averaged, with higher scores representing more frequent technoference in mother-child activities (McDaniel & Radesky, 2018b).

*Infant Negative Emotionality.* Based on previous studies suggesting that infant negative emotionality may influence infants' response to the SFP (Myruski et al., 2017), infants' negative emotionality was also included as a covariate. Mothers completed the Infant Behavior Questionnaire Revised-Very Short Form (IBQ-R-VSF) (Putnam et al., 2014), a caregiver report of infant temperament measuring positive affectivity, negative emotionality, and orienting and regulatory capacity. For the current study, the negative emotionality scale was used ($\alpha = 0.75$).

## 2.4. Analytic strategy

We conducted a power analysis based on 5000 Monte Carlo simulations using the powerCurve function from the simr package (Green & Macleod, 2016). The simulation revealed that a sample size of 105 subjects provides sufficient power (beta = 0.8) to detect a medium effect size ($\eta^2_p = .6$), with a corrected α level of 0.0125.

Preliminary analyses included evaluation of correlations between study variables and the control variables. To examine the study hypotheses, a series of mixed-effects analyses of variance (ANOVA) were conducted. Condition was the between-participants variable (1. Mobile-phone-disruptions, 2. Social-disruptions, 3. Undisrupted-play) and phase (1. Free play, 2. Texting/Conversation with experimenter/Free-play, 3. Free play) the within-participants variable. The dependent variables were mean HR and NA in each phase and HR-change and NA change scores between phases. We first compared mean HR and NA between phases and conditions to examine whether there were significant changes in these measures between phases. Then, to compare the *magnitude* of change in these variables between conditions, we compared the HR and NA-change scores between the three experimental conditions. Bonferroni-corrected pairwise comparisons were applied. To further investigate significant interaction effects, we ran repeated measures ANOVAs separately for each experimental condition. This allowed us to examine the within-subjects changes in the dependent variables across the different phases of the experimental paradigm.

Finally, to examine whether infants' behavioral and physiological responses were coordinated, we estimated Pearson correlations between the HR and NA-change scores for each experimental condition.

## 3. Results

### 3.1. Preliminary analyses

Bivariate correlations between the primary study variables and the covariates were estimated (Table 2). No significant correlations were found between covariates and the study variables. Additionally, one way ANOVA analyses revealed no significant differences between the three conditions in infant negative emotionality, $F$ (2,103) = 1.14, $p = .323$, and technoference in mother-child activities, $F$ (2,102) = 1.37, $p = .257$. Therefore, technoference and negative emotionality were not included in the main analysis.

### 3.2. Main analysis

See Table 3 for means and standard deviations of heart rate and negative affect by phase and condition.

#### 3.2.1. Physiological changes

*Mean HR.* There was a significant main effect for phase $F$ (2,206) = 25.80, $p < .001$, $\eta p^2 = 0.356$ such that mean HR increased between phase 1 to phase 2 ($p < .001$), and decreased between phase 2 to phase 3 ($p < .001$). There was also a signifcant main effect for conditon $F$ (2,103) = 3.33, $p = .039$, $\eta p^2 = 0.061$, with infants in the undisrupted-play condition having overall higher HR compared to infants in the social-disruptions condition ($p = .012$). Finally, there was a signifcant interaction between condition and phase $F$ (4,206) = 6.06, $p < .001$, $\eta p^2 = 0.105$. Repeated measures ANOVAs revealed that the increase in HR between phases 1 and 2 followed by the decrease between phases 2 and 3 was evident in both the mobile-phone-disruptions condition $F$ (2,72) = 17.95, $p < .001$, $\eta p^2 = 0.333$ and the social-disruptions condition $F$ (2,64) = 6.87, $p = .002$, $\eta p^2 = 0.177$ (see Fig. 2). To investigate whether infants returned to their baseline level of reactivity in phase 3, we examined mean differences in HR between the first- and third phases. No significant differences were found for infants in both the mobile-phone- and social-disruptions conditions ($M = -0.13$, $SD = 0.76$, $p = 1.00$; $M = -1.11$, $SD = 0.80$, $p = .50$, respectively), suggesting that in both conditions infants' HR returned to its initial level. In the undisrupted-play condition $F$ (2,70) = 9.89, $p < .001$, $\eta p^2 = 0.220$, there was an increase in HR between phases 1 and 2, but no significant change between phases 2 and 3.

*HR-change scores.* A comparison of the HR-change scores between phases 1 and 2 $F$ (2,103) = 4.46, $p = .014$, $\eta p^2 = 0.080$ showed that infants in the mobile-phone-disruptions condition showed the highest increase in HR ($M = 0.35$, $SD = 1.17$) compared to infants in the social-disruptions ($M = -0.13$, $SD = 1.03$) and undisrupted-play ($M = -0.23$, $SD = 0.61$) conditions ($p = .024$, $p = .006$, respectively). No differences in HR-change between phases 1 and 2 were found between infants in the social-disruptions and undisrupted-play conditions ($p = .667$). Infants in the mobile-phone-disruptions condition ($M = -0.42$, $SD = 1.24$) also showed the highest decrease in HR between phases 2 and 3 $F$ (2,103) = 10.84, $p < .001$ $\eta p^2 = 0.174$ compared to infants in the social-disruptions ($M = -0.04$, $SD = 0.76$) and undisrupted-play ($M = 0.45$, $SD = 0.66$) conditions ($p = .03$, $p = .001$, respectively). Infants in the social-disruptions condition showed a larger decrease in HR compared to infants in the undisrupted-play condition ($p = .01$).

**Table 3**

Means and (standard deviations) of heart rate and negative affect by phase and condition.

| Phase | | Mobile-phone-disruptions | Social-disruptions | Undisrupted-play |
|---|---|---|---|---|
| 1) Free-play | *Heart Rate* | 127.37 (10.05) | 124.14 (9.47) | 130.04 (10.11) |
| | *Negative Affect* | .08 (.19) | .03 (.08) | .01 (.02) |
| 2) Mobile/Social Disruptions/ Free- Play | *Heart Rate* | 132.24 (9.53) | 127.10 (9.81) | 131.82 (9.68) |
| | *Negative Affect* | .39 (.42) | .11 (.14) | .03 (.06) |
| 3) Free-play | *Heart Rate* | 127.50 (10.33) | 125.25 (9.33) | 132.39 (10.74) |
| | *Negative Affect* | .14 (.35) | .07 (.16) | .11 (.38) |

#### 3.2.2. Behavioral changes

*Mean NA.* There was a significant main effect for phase $F$ (2,206) = 9.22, $p < .001$, $\eta p^2 = 0.082$ such that NA increased between phase 1 to phase 2 ($p < .001$). NA also decreased between phase 2 to phase 3, however the decrease was insignificant ($p = .062$). There was also a signifcant main effect for conditon $F$ (2,103) = 9.35, $p < .001$, $\eta p^2 = 0.154$, with infants in the mobile-phone-disruptions condition displaying overall higher levels of NA comapred to inafnts in in the social-disruptions ($p = .001$) and undisrupted-play ($p < .001$) conditions. Finally, there was a signifcant interaction between condition and phase $F$ (4,206) = 6.25, $p < .001$, $\eta p^2 = 0.108$. Repeated measures ANOVAs were run separately for each experimental condition to further understand the interaction effect (see Fig. 2). These analyses revealed that in both the mobile-phone-disruptions $F$ (2,72) = 10.57, $p < .001$, $\eta p^2 = 0.227$ and social-disruptions conditions $F$ (2,64) = 3.52, $p = .035$, $\eta p^2 = 0.399$ there was a significant increase in NA between phases 1 and 2. In the mobile-phone-disruptions condition, this increase was followed by a significant decrease between phases 2 and 3. No significant differences were found in mean NA between the first- and third phases for infants in both mobile-phone- and social-disruptions conditions ($M = -0.05$, $SD = 0.05$, $p = .80$; $M = -0.03$, $SD = 0.05$, $p = 1.00$, respectively), suggesting

**Table 2**

Means, Standard Deviations, and Correlations Among the covariates and Study Variables (N = 106).

| | Variable | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Negative emotionality | 4.20 | 1.00 | – | | | | | | | | | | | |
| 2 | Technoference | 1.65 | .54 | .05 | – | | | | | | | | | | |
| 3 | Phase 1 - HR mean | 127.27 | 10.09 | .04 | -.03 | – | | | | | | | | | |
| 4 | Phase 2 - HR mean | 130.50 | 9.85 | .06 | -.06 | .89** | – | | | | | | | | |
| 5 | Phase 3 - HR mean | 128.46 | 10.51 | .05 | -.04 | .89** | .86** | – | | | | | | | |
| 6 | HR-change 1-2 | .01 | 1.01 | .04 | -.06 | .00 | .44** | .13 | – | | | | | | |
| 7 | HR-change 2-3 | -.03 | .98 | .01 | .02 | .24* | -.99 | .50** | -.49** | – | | | | | |
| 8 | Phase 1 - NA mean | .04 | .13 | .06 | -.00 | .02 | -.02 | .00 | -.11 | .04 | – | | | | |
| 9 | Phase 2 - NA mean | .18 | .31 | -.06 | .02 | -.05 | .19* | -.07 | .56** | -.48** | .17 | – | | | |
| 10 | Phase 3 - NA mean | .11 | .31 | -.11 | .11 | .03 | .00 | .12 | -.05 | .24* | .28** | .17 | – | | |
| 11 | 1-2 NA-change | .02 | 1.01 | -.07 | .02 | -.06 | .20* | -.07 | .59** | -.50** | .01 | .98** | .12 | – | |
| 12 | 2-3 NA-change | -.01 | .99 | -.10 | .10 | .04 | -.02 | .14 | -.15 | .33** | .25** | .00 | .98** | -.03 | – |

*$p < .05$, **$p < .01$.

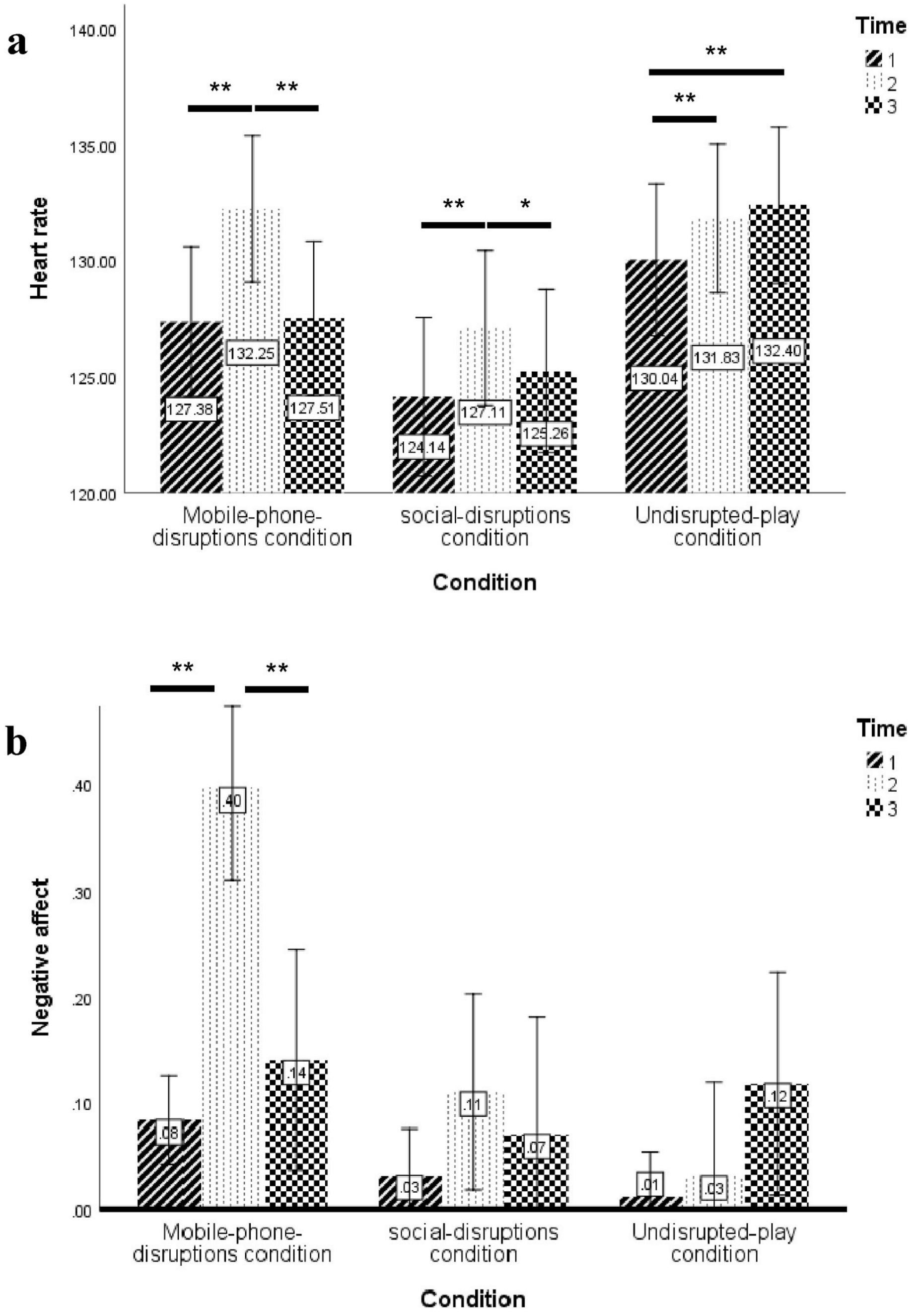

**Fig. 2.** Mean heart rate (a) and negative affect (b) for each phase by experimental condition. *p < .05,**p < .01.

that in both conditions infants' NA decreased to its initial level. In the undisrupted-play condition there were no significant differences in NA between phases $F$ (2,70) = 2.57, $p = .083$, $\eta p^2 = 0.069$.

*NA-change scores.* A comparison of the NA-change scores $F$ (2,103) = 15.78, $p < .001$, $\eta p^2 = 0.235$ showed that infants in the mobile-phone-disruptions ($M = 0.67$, $SD = 1.43$) showed the highest increase in NA between phases 1 and 2 compared to infants in the social-disruptions ($M$ = -0.20, $SD = 0.46$) and undisrupted-play ($M$ = -0.44, $SD = 0.19$) conditions ($p < .001$), while infants in the social-disruptions and undisrupted-play condition did not differ ($p = .27$). There were no significant differences between the three conditions in NA-change between phases 2 and 3 $F$ (2,103) = 0.34, $p = .713$.

*3.2.3. Associations between physiological and behavioral changes*

For both the mobile-phone-disruptions and social-disruptions conditions, HR and NA-changes scores between phases 1 and 2 were significantly correlated ($r = 0.70$, $p < .001$; $r = 0.39$, $p = .024$, respectively). Fisher z test revealed a stronger correlation in the mobile-phone-disruptions condition in comparison to the social-disruptions condition ($z = 1.81$, $p = .03$). No significant associations were found between HR and NA change scores in the undisrupted-play condition ($r = -0.10$, $p = .558$). HR and NA change scores between phases 2 and 3 were significantly correlated only in the mobile-phone-disruptions condition ($r = 0.56$, $p < .001$), and not in the social-disruptions ($r = 0.04$, $p = .810$) and undisrupted-play conditions ($r = 0.16$, $p = .329$).

## 4. Discussion

The goal of the current study was to understand how PMU during parent-child interactions may impact children's psychophysiological functioning. To that aim, we examined changes in infants' HR and observed NA across a modified still-face paradigm that provides a context for examining the effects of PMU. To the best of our knowledge, this is the first study that examined the impact PMU may have on infants' physiological reactivity. Based on previous research using the classic still-face paradigm (Bazhenova et al., 2001; Haley & Stansbury, 2003), we expected an increase in both HR and NA between the free-play and disruption episodes. To examine whether children's responses are uniquely affected by PMU, we also examined behavioral and physiological responses to social disruptions and undisrupted-play control conditions. We found differential patterns of infants' HR and NA reactivity between the three experimental conditions. Specifically, infants in the mobile-phone-disruptions condition exhibited the greatest increase in NA and HR between the first and second phase and the greatest decrease in HR levels between the second and third phase compared to infants in the control conditions.

Findings from the current study are consistent with previous research, demonstrating changes in NA across the modified SFP (Myruski et al., 2018; Stockdale et al., 2020). Specifically, infants in the mobile-phone-disruptions condition showed an increase in NA during the disruptions phase compared to the free-play phase. Similarly, infants in the social-disruptions condition also demonstrated an increase in NA albeit, when accounting for infants' previous NA levels, NA-change did not differ from infants in the undisrupted-play condition.

A decrease in NA between the second and third phases was evident in the mobile-phone-disruptions condition. Nonetheless, we did not find significant differences between the three conditions in the NA-change scores. A previous study indicated no differences in NA levels between the second and third phases across a modified SFP (Stockdale et al., 2020). Thus, it is plausible that infants who responded to disruptions with an increase in NA continued to exhibit some degree of NA during the reunion phase. Consistent with this finding, Weinberg and Tronick (1996) showed, using the classic still-face paradigm, that infants displayed a mixed pattern of both positive and negative affect during the reunion episode, suggesting a carryover effect of negative affect from the still-face to the reunion episode.

Our results show an increase in HR between phases 1 and 2 in all three experimental conditions. This general increase in physiological arousal may reflect a stimulus overload in response to the novel toys presented in the play interaction, which may be arousing for infants (Field, 1981). It is also possible that infants' motor activity increased during the initial introduction to the novel play situation, resulting in slight increases in HR (Porges et al., 2007). However, a comparison of HR-change scores revealed a significantly greater increase among infants in mobile-phone-disruptions than in the control conditions. Moreover, HR change did not differ between infants in the social-disruptions and undisrupted-play conditions. The acceleration in HR observed in the mobile-phone-disruptions condition, as well as its magnitude (5 bpm), is consistent with previous research, demonstrating increases in HR during the still-face episode compared to the free-play episode in the classic still-face paradigm (Bazhenova et al., 2001; Haley & Stansbury, 2003; Moore & Calkins, 2004; Weinberg & Tronick, 1996). This pattern of autonomic reactivity indicates that infants experienced the mobile phone disruptions as stressful, similar to the reaction to the extreme case of maternal unresponsiveness in the classic still-face paradigm.

In both mobile-phone-disruptions and social-disruptions conditions, once mothers recommenced the interaction with their infants, infants' HR and NA levels decreased to their initial levels. These findings are consistent with previous studies suggesting HR decrease from still-face to reunion episodes across the classic still-face paradigm (Haley & Stansbury, 2003; Weinberg & Tronick, 1996). This phase of the interaction constitutes a return to "normal" social interaction. In addition, during the reunion phase, mothers are likely to react to their infants' distress, helping them soothe and resume play. HR-decrease during this phase was the highest among infants in the mobile-phone-disruptions condition.

Stress responses involve behavioral and physiological systems, which help the organism restore and maintain homeostasis when disturbed (Allen et al., 2014). In the classic still-face episode, increases in HR were associated with increased emotional arousal (Bazhenova et al., 2001), suggesting that these two domains were linked. Correspondingly, we found positive correlations between HR and NA-changes scores between phases 1 and 2, for both the mobile-disruptions and social-disruptions conditions, with stronger correlations in the former. Between phases 2 and 3, HR and NA-change scores were correlated only in the mobile-disruptions condition. Haley and Stansbury (2003) suggest that behavioral and physiological systems become more tightly coupled under conditions of greater stress. Thus, the strong coupling in the mobile-phone-disruptions condition further confirms the stressful nature of maternal mobile-phone use for infants.

The behavioral and physiological reactivity patterns observed in the social-disruptions condition indicate that infants in this group experienced less stress than infants in the mobile-phone-disruptions condition. Social conversations may allow more flexible attention alternating on behalf of the parent, enabling the parent to continue responding to the infants' social bids (Vanden Abeele et al., 2020). Moreover, a social conversation can be considered a joint interruption, in which the dyad still maintains a shared focus of attention, although the focus has shifted (Reed et al., 2017). In the social disruptions condition, a research assistant conducted a conversation with the mother that did not actively involve the infant. Although this situation can be somewhat stressful for infants, the social nature of this situation provided a context that they could have potentially perceive and understand. Infants are able to perceive social interactions that they are not actively involved in (Augusti et al., 2010; Thorgrimsson et al., 2015). One-year-old infants' joint attention skills, such as their ability to follow the gaze shift/head turn of another to locate an event of interest (Mundy et al., 2007), enable them to tune into ongoing social interactions. Conversely, in the mobile-phone-disruptions condition, when mothers were engaged with the mobile device, the context may have been less clear for infants and more excluding, plausibly leading to elevated stress responses.

The results from the current study should be considered in light of several limitations. First, this study used a cross-sectional design that cannot shed light on the long-term effects of PMU on children's health and well-being. As elevated stress reactivity confers risk for both health and behavioral problems (Gianaros & Jennings, 2018; Patrick, 2008), it is imperative to conduct longitudinal research to understand the effect of continuous exposure to these stressful conditions on children's development. Second, this study focused on infants at the end of their first year of life. As previous research suggests that parental mobile-phone interferences can affect children from early childhood through adolescence (McDaniel & Radesky, 2018b; Sundqvist et al., 2020; Wong et al., 2020). Future studies should focus on the impact that PMU may have on stress response across different developmental stages. Finally, the current study was conducted in a laboratory setting, infants' and mothers' mobility was restricted, and a limited selection of toys was offered. These controlled circumstances are different than real-life parent-child interactions involving disruptions in social-emotional communication. Conducting psychophysiological measurements in naturalistic settings will increase the ecological validity of the findings.

## 5. Conclusion

Parent distraction with mobile phones has become a common phenomenon that elicits negative behaviors among children. Findings from this study are the first to suggest that PMU evokes a psychophysiological stress response in infants, as evident in increases in HR and NA, followed by post-PMU decreases. These patterns differ from social disruptions, in which psychophysiological reactivity was lower. Given that most children in modern societies are exposed to PMU daily, practical guidelines and programs should be formulated to promote healthy mobile device use during parent-child interactions.

## Credit author statement

Yael Rozenblatt-Perkal conceptualized and designed the study, coordinated and supervised data collection, carried out the initial analyses drafted the initial manuscript, and reviewed and revised the manuscript. Dr Michael Davidovitch conceptualized and designed the study and reviewed and revised the manuscript. Dr Noa Gueron-Sela conceptualized and designed the study, supervised data collection, and critically reviewed and revised the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

## Funding

The study was supported by the KSM Research and Innovation Institute, Maccabi Healthcare Services and Society of Research in Child Development, Small Grants Program for Early Career Scholars.

## Declaration of competing interest

None.

## References

Allen, A. P., Kennedy, P. J., Cryan, J. F., Dinan, T. G., & Clarke, G. (2014). Biological and psychological markers of stress in humans: Focus on the trier social stress test. *Neuroscience & Biobehavioral Reviews, 38*, 94–124. https://doi.org/10.1016/j.neubiorev.2013.11.005

Augusti, E. M., Melinder, A., & Gredebäck, G. (2010). Look who's talking: Pre-verbal infants' perception of face-to-face and back-to-back social interactions. *Frontiers in Psychology, 1*(OCT), 1–7. https://doi.org/10.3389/fpsyg.2010.00161

Bazhenova, O. V., Plonskaia, O., & Porges, S. W. (2001). Vagal reactivity and affective adjustment in infants during interaction challenges. *Child Development, 72*(5), 1314–1326. https://doi.org/10.1111/1467-8624.00350

Bowlby, J. (1982). *Attachment and loss* (Vol. 1). New York, NY: Basic Books (Original work published 1969).

Burt, K. B., & Obradovic, J. (2013). The construct of psychophysiological reactivity : Statistical and psychometric issues. *Developmental Review, 33*(1), 29–57. https://doi.org/10.1016/j.dr.2012.10.002

Dietrich, A., Riese, H., Sondeijker, F. E. P. L., Greaves-Lord, K., Van Roon, A. M., Ormel, J., Neeleman, J., & Rosmalen, J. G. M. (2007). Externalizing and internalizing problems in relation to autonomic function: A population-based study in preadolescents. *Journal of the American Academy of Child & Adolescent Psychiatry, 46*(3), 378–386. https://doi.org/10.1097/CHI.0b013e31802b91ea

Elias, N., Lemish, D., Dalyot, S., & Floegel, D. (2020). "Where are you?" an observational exploration of parental technoference in public places in the US and Israel. *Journal of Children and Media*, 1–13. https://doi.org/10.1080/17482798.2020.1815228, 00 (00).

Field, T. M. (1981). Infant gaze aversion and heart rate during face-to-face interactions. *Infant Behavior and Development, 315*(4), 307–315.

Fleming, S., Thompson, M., Stevens, R., Heneghan, C., Plüddemann, A., Maconochie, I., Tarassenko, L., & Mant, D. (2011). Normal ranges of heart rate and respiratory rate in children from birth to 18 years of age : A systematic review of observational studies. *The Lancet, 377*(9770), 1011–1018. https://doi.org/10.1016/S0140-6736(10)62226-X

Gianaros, P. J., & Jennings, J. R. (2018). Host in the machine: A neurobiological perspective on psychological stress and cardiovascular disease. *American Psychologist, 73*(8), 1031–1044. https://doi.org/10.1037/amp0000232

Green, P., & Macleod, C. J. (2016). SIMR : an R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution, 7*(4), 493–498. https://doi.org/10.1111/2041-210X.12504

Haley, D. W., & Stansbury, K. (2003). Infant stress and parent responsiveness: Regulation of physiology and behavior during still-face and reunion. *Child Development, 74*(5), 1534–1546. https://doi.org/10.1111/1467-8624.00621

Javorka, K., Javorka, M., Tonhajzerova, I., Calkovska, A., Lehotska, Z., Bukovinska, Z., & Zibolen, M. (2011). Determinants of heart rate in newborns. *Acta Medica Martiniana, 11*(2), 7–16.

Kantor, L., Curtisova, V., & Dubrava, L. (2003). Development of heart rate variability during the first three days of life. *Acta Medica Martiniana, 3*(3), 22–29 ().

Kildare, C. A., & Middlemiss, W. (2017). Impact of parents mobile device use on parent-child interaction: A literature review. *Computers in Human Behavior, 75*, 579–593. https://doi.org/10.1016/j.chb.2017.06.003

McDaniel, B. T. (2019). Parent distraction with phones, reasons for use, and impacts on parenting and child outcomes: A review of the emerging research. *Human Behavior and Emerging Technologies, 1*(2), 72–80. https://doi.org/10.1002/hbe2.139

McDaniel, B. T., & Radesky, J. S. (2018a). Technoference: Longitudinal associations between parent technology use, parenting stress, and child behavior problems. *Pediatric Research, 84*(2), 210–218. https://doi.org/10.1038/s41390-018-0052-6

McDaniel, B. T., & Radesky, J. S. (2018b). Technoference: Parent distraction with technology and associations with child behavior problems. *Child Development, 89*(1), 100–109. https://doi.org/10.1111/cdev.12822

Moore, G. A., & Calkins, S. D. (2004). Infants' vagal regulation in the still-face paradigm is related to dyadic coordination of mother-infant interaction. *Developmental Psychology, 40*(6), 1068–1080. https://doi.org/10.1037/0012-1649.40.6.1068

Mundy, P. (2016). *Autism and joint attention: Developmental, neuroscience and clinical fundamentals*. New York, NY: Guilford Publications Inc.

Mundy, P. (2018). A review of joint attention and social-cognitive brain systems in typical development and autism spectrum disorder. *European Journal of Neuroscience, 47*(6), 497–514. https://doi.org/10.1111/ejn.13720

Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development, 78*(3), 938–954. https://doi.org/10.1111/j.1467-8624.2007.01042.x

Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development, 21*(3), 469–482.

Myruski, S., Gulyayeva, O., Birk, S., Pérez-Edgar, K., Buss, K. A., & Dennis-Tiwary, T. A. (2018). Digital disruption? Maternal mobile device use is related to infant social-emotional functioning. *Developmental Science, 21*(4), 1–9. https://doi.org/10.1111/desc.12610

Patrick, C. J. (2008). Review. Psychophysiological correlates of aggression and violence: An integrative review. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1503), 2543–2555. https://doi.org/10.1098/rstb.2008.0028

Porges, S. W., & Furman, S. A. (2011). The early development of the autonomic nervous system provides a neural platform for social Behaviour : A polyvagal perspective. *Infant and Child Development, 20*(1), 106–118. https://doi.org/10.1002/icd

Porges, S. W., Heilman, K. J., Bazhenova, O. V., & Doussard-roosevelt, J. A. (2007). Does motor activity during psychophysiological paradigms confound the quantification and interpretation of heart rate and heart rate variability measures in young Children ? *Developmental Psychobiology: The Journal of the International Society for Developmental Psychobiology, 49*(5), 485–494. https://doi.org/10.1002/dev

Putnam, S. P., Helbig, A. L., Gartstein, M. A., Rothbart, M. K., & Leerkes, E. (2014). Development and assessment of short and very short forms of the infant behavior questionnaire-revised. *Journal of Personality Assessment, 96*(4), 445–458. https://doi.org/10.1080/00223891.2013.841171

Radesky, J. S., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., Augustyn, M., & Silverstein, M. (2014). Patterns of mobile device use by caregivers and children during meals in fast food restaurants. *Pediatrics, 133*(4). https://doi.org/10.1542/peds.2013-3703

Reed, J., Hirsh-Pasek, K., & Golinkoff, R. M. (2017). Learning on hold: Cell phones sidetrack parent-child interactions. *Developmental Psychology, 53*(8), 1428–1436. https://doi.org/10.1037/dev0000292

Smith, R. L., Wathen, E. R., Abaci, P. C., Von Bergen, N. H., Law, I. H., Dick, M. D., & Dove, E. L. (2009). September). Heart rate variability analysis in normal infants and infants with single ventricle anatomy using power spectral density. *2009 36th annual computers in cardiology conference (CinC)*. IEEE.

Sroufe, L. A., & Waters, E. (1977). Heart rate as a convergent measure in clinical and developmental research. *Merrill-Palmer Quarterly, 23*, 3–27. Retrieved from https://www.jstor.org/stable/23083894.

Stevenson-Hinde, J., & Marshall, P. J. (1999). Behavioral inhibition, heart period, and respiratory sinus arrhythmia: An attachment perspective. *Child Development, 70*(4), 805–816. https://doi.org/10.1111/1467-8624.00058

Stockdale, L. A., Porter, C. L., Coyne, S. M., Essig, L. W., Booth, M., & Schvaneveldt, E. (2020). Infants' response to a mobile phone modified still- face paradigm : Links to maternal behaviors and beliefs regarding technoference. *Infancy, 25*(5), 571–592. https://doi.org/10.1111/infa.12342

Sundqvist, A., Heimann, M., & Koch, F. S. (2020). Relationship between family technoference and behavior problems in children aged 4-5 years. *Cyberpsychology, Behavior, and Social Networking, 23*(6), 371–376. https://doi.org/10.1089/cyber.2019.0512

Thorgrimsson, G. B., Fawcett, C., & Liszkowski, U. (2015). 1- and 2-year-olds' expectations about third-party communicative actions. *Infant Behavior and Development, 39*, 53–66. https://doi.org/10.1016/j.infbeh.2015.02.002

Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of the American Academy of Child Psychiatry, 17*(1), 1–13. https://doi.org/10.1016/S0002-7138(09)62273-1

Vanden Abeele, M. M. P., Abels, M., & Hendrickson, A. T. (2020). Are parents less responsive to young children when they are on their phones? A systematic naturalistic observation study. *Cyberpsychology, Behavior, and Social Networking, 23*(6), 363–370. https://doi.org/10.1089/cyber.2019.0472

Weinberg, M. K., & Tronick, E. Z. (1996). Infant affective reactions to the resumption of maternal interaction after the still-face. *Child Development, 67*(3), 905–914. https://doi.org/10.1111/j.1467-8624.1996.tb01772.x

White, B. P., Gunnar, M. R., Larson, M. C., Donzella, B., & Barr, R. G. (2000). Behavioral and physiological responsivity , sleep , and patterns of daily cortisol production in infants with and without. *Colic, 71*(4), 862–877.

Wolfers, L. N., Kitzmann, S., Sauer, S., & Sommer, N. (2020). Phone use while parenting: An observational study to assess the association of maternal sensitivity and smartphone use in a playground setting. *Computers in Human Behavior, 102*, 31–38. https://doi.org/10.1016/j.chb.2019.08.013. March 2019.

Wong, R. S., Tung, K. T. S., Rao, N., Leung, C., Hui, A. N. N., Tso, W. W. Y., Fu, K. W., Jiang, F., Zhao, J., & Ip, P. (2020). Parent technology use, parent–child interaction, child screen time, and child psychosocial problems among disadvantaged families. *The Journal of Pediatrics, 226*, 258–265. https://doi.org/10.1016/j.jpeds.2020.07.006

Zahn-waxler, C., Robinson, J. L., & Emde, R. N. (1992). The development of empathy in twins. *Developmental Psychology, 28*(6), 1038–1047.